DETERMINATIVE MINERALOGY

WITH TABLES

FOR THE DETERMINATION OF MINERALS BY MEANS OF THEIR CHEMICAL AND PHYSICAL CHARACTERS

BY

J. VOLNEY LEWIS

Professor of Geology and Mineralogy in Rutgers College

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PREFACE

THIS book has been prepared primarily for the use of students in determinative mineralogy, but it has also been made sufficiently inclusive to meet the demands of the geologist and the mining engineer in all but the rarest cases. The accompanying tables include 380 minerals, or from 100 to 150 more than are fully described in the current textbooks. Besides the more common minerals and those of economic value as ores or otherwise, many of the less common and even rarer species have also been included. Some idea of relative importance is suggested by the sizes of type in which the names are printed. Those that have been omitted are very rare and, from a practical point of view, of little present importance.

Chemical composition is considered to be the most fundamental property of a mineral; and many species, particularly among the ores, cannot be determined with certainty except by means of chemical tests. The diagnostic value of physical characters in many cases is fully recognized, however, and half the space of the tables is devoted to a statement of these properties. A special table has also been appended in which the minerals are arranged according to crystallization, luster, and hardness. The plan of the Brush-Penfield tables has been followed, in the main, but with considerable modification and rearrangement and with much condensation. Chemical

formulas and the descriptions of physical properties have been thoroughly revised and several new species have been added. In order to simplify the procedure and facilitate the use of the tables, the more difficult and elaborate chemical tests have been avoided; and blowpipe or "dry" tests have been preferred, in general, to those made in the "wet" way.

It is intended that the tables should not only furnish a name by which an unknown mineral may be called, but should also lead the student to acquire for himself a knowledge of what the mineral really is, both chemically and physically. The constant use of a good treatise on descriptive mineralogy to supplement the tables, while not absolutely required, is recommended, especially for the student. In order to facilitate such use, page references to Dana's "System of Mineralogy" (6th edition) and to Dana's "Textbook of Mineralogy" (new edition) are inserted after the name of each mineral. These works are designated respectively by the initials "S" and "T."

I am greatly indebted to Dr. Henry S. Washington for valuable criticism and for his kindness in reading the proofs in my absence. Mr. W. S. Valiant, of the Geological Museum of Rutgers College, has also rendered important assistance in correcting the manuscript.

J. Volney Lewis.

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June 20, 1912.

CONTENTS

	PAGE
Apparatus	1
Reagents	4
Blowpipe Operations and Chemical Tests	6
Reactions for the Elements	26
Crystallization	47
Descriptive and Technical Terms	53
Table of Chemical Elements	58
Abbreviations	60
Precautions Concerning Use of Tables	63
Determinative Tables	64
Minerals Arranged by Crystallization, Luster, and Hardness	135
General Index	141
Index to Minerals	145

DETERMINATIVE MINERALOGY

APPARATUS

Blowpipe. The ordinary brass jeweler's blowpipe, 10 or 12 inches long, serves very well. The more expensive instrument with a platinum tip is more durable. In either case it is essential that the tip shall be perforated with a very small, smooth hole.

Lamp. (*a*) The ordinary Bunsen gas burner (Fig. 10), with a tube to be inserted for blowpiping (Figs. 2–6). The tube is flattened to a narrow slit at the top and cut off slanting, with or without projecting points to form a rest for the blowpipe tip. (*b*) A lamp to use olive oil or other vegetable oil, or (*c*) one using tallow, paraffin, or other solid fuel. The last is most convenient for portable use. It is lighted with a match and the flame is then blown steeply downward for a few seconds in order to melt some of the fuel next to the wick. The heat of the flame then keeps it going. (*d*) Ordinary candles (preferably large and of tallow) serve very well. In heating a test tube with a luminous flame the tube should be held entirely above the luminous part, in order to avoid blackening it with a deposit of soot; or an alcohol lamp may be provided for this purpose where gas is not obtainable.

Forceps. For most purposes plain iron forceps, 4 or 5

inches long and filed down to small points, can be used. Those with platinum points are better but expensive.

Charcoal. Best from soft wood (willow, pine, etc.). Convenient sizes, about $\frac{1}{2} \times 1 \times 4$ inches, may be purchased. Used as a support in many operations with the blowpipe (Figs. 5, 6), and in making reductions the carbon assists the flame.

Platinum Wire. A thin wire (24 or 25 B. & S. gage, 0.4 or 0.5 mm. diameter) about 3 inches long and sealed in a small glass tube for a handle (Fig. 9). Most used with a circular loop, $\frac{1}{8}$ inch (3 mm.) in diameter, at the end to hold a bead of borax, s.ph., or other flux.

Open and Closed Tubes. To be made of "combustion" tubing about $\frac{3}{16}$ inch internal diameter. For open tubes cut with a file into 4-inch lengths and use either straight, or better, with a bend near one end (Fig. 8), which may be made by heating until the glass is soft. For closed tubes (Fig. 7), cut into 5- or 6-inch lengths, heat the middle in the Bunsen flame or blast lamp, turning slowly in order to heat all sides alike; when soft pull quickly apart. Hold the tapering part of each tube thus formed in the flame and pull away the slender glass tip.

Hammer. Any small hammer will serve. For the special hammer, a wire handle is best.

Anvil. Any smooth flat block of iron or steel. The flat side of a hammer is good.

Magnet. A magnetized knife blade or chisel or a small horse-shoe magnet.

Blue and Green Glass. Two pieces of each, 2 or 3 inches square, for observing flame colors.

Test Tubes. Good sizes are $4 \times \frac{1}{2}$ and $5 \times \frac{5}{8}$ inches.

Test Tube Holder. Of brass wire or wood best—for holding hot tubes.

Streak Plate. Unglazed porcelain; a convenient size is $1\frac{1}{2} \times 3$ inches.

In addition to the above the following articles will be found convenient in the laboratory. For portable outfits they may be dispensed with.

Watch Glasses. Shallow, 2 inches in diameter.

Test Tube Support. Wood, with several holes larger than the tubes. Easily made.

Agate Mortar. $1\frac{1}{4}$ inches diameter or larger, with agate pestle.

Diamond Mortar. Of steel; two-piece form is best. Useful when only small particles of a mineral are obtainable.

Glass Funnel. Two inches in diameter or larger.

Filter Paper. Round and twice the diameter of the funnel.

Charcoal Brush. For removing sublimates from charcoal an old toothbrush or any stiff brush may be used; or they may be scraped off with a knife.

Gypsum Tablets. Thin paste of plaster of Paris is spread about $\frac{1}{4}$ inch thick on a sheet of glass that has been slightly oiled. While still soft cut the paste with a knife into rectangles about $1\frac{1}{2} \times 4$ inches. These are readily removed after the plaster hardens. Used for support, like charcoal, and show some sublimates better.

Porcelain Crucible. With support. Sometimes useful for burning a filter paper.

REAGENTS

To be used dry:

Sodium Carbonate, or soda, Na_2CO_3; or sodium bicarbonate, common baking soda, $NaHCO_3$.

Sodium Tetraborate, or borax, $Na_2B_4O_7 \cdot 10H_2O$.

Sodium Ammonium Phosphate, also called "phosphorus salt" and "microcosmic salt," $HNaNH_4PO_4 \cdot 4H_2O$. Loses NH_4OH and $4H_2O$ on heating, becoming *sodium metaphosphate* ($NaPO_3$, abbreviated s.ph.).

Test Papers, small strips of blue and red litmus paper and yellow turmeric paper.

Potassium Bisulphate, $KHSO_4$.

"*Boric Acid Flux*," 1 part finely powered fluorite (CaF_2) with 4 parts potassium bisulphate ($KHSO_4$).

"*Bismuth Flux*," 1 part potassium iodide (KI), 2 parts sulphur (S), and 1 part potassium bisulphate ($KHSO_4$).

Tin, foil or granulated. Scraps of tin cans or other tin plate will serve.

Occasional use will also be found for the following:

Zinc, granulated or scraps of sheet zinc.

Galena, PbS, powdered.

Gypsum, $CaSO_4 \cdot 2H_2O$, powdered.

To be used in liquid form:

Water, H_2O, distilled or rain water is best; for most purposes any clear water that is not "hard" will serve.

Hydrochloric Acid, HCl ("muriatic acid"), for most purposes diluted with an equal quantity of water.

The acids named below are more dangerous to handle and less useful than hydrochloric:

Nitric Acid, HNO_3 ("aqua fortis").

Aqua Regia, 3 parts hydrochloric and 1 part nitric acid.

Sulphuric Acid, H_2SO_4 ("oil of vitriol"). In diluting add the acid very slowly to water.

Ammonium Hydroxide, or ammonia, NH_4OH.

Potassium Hydroxide, KOH ("caustic potash"). Best kept as sticks broken to short bits and placed in a well-stoppered bottle—to be dissolved in a little water as needed.

Ammonium Molybdate, $(NH_4)_2MoO_4$. Dissolve the crystals in water that has been made alkaline with ammonia. For use acidify a little in a test tube with HNO_3; the ppt. that forms is quickly cleared up by further addition of acid.

Cobalt Nitrate, $Co(NO_3)_2$. Dissolve the crystals in 10 parts of water.

Ammonium Carbonate, $(NH_4)_2CO_3$. Dissolve in water as needed.

Ammonium Oxalate, $(NH_4)_2C_2O_4 \cdot 2H_2O$. Dissolve in water as needed.

Sodium Phosphate, Na_2HPO_4. Dissolve in water.

Barium Chloride, $BaCl_2$. Dissolve in water.

Silver Nitrate, $AgNO_3$. Dissolve in water and keep in a bottle well wrapped with opaque paper.

Potassium Ferrocyanide, $K_4Fe(CN)_6 \cdot 3H_2O$. Dissolve in water.

Potassium Ferricyanide, $K_6Fe_2(CN)_{12}$. Dissolve a little at a time in water as needed. The solution does not keep well.

BLOWPIPE OPERATIONS AND CHEMICAL TESTS

1. Blast. The blast of the blowpipe should not be blown from the lungs and should not interfere with regular breathing. Distend the cheeks fully and, while breathing through the nose, allow the air to escape from the mouth through the blowpipe without making any effort to blow. Before the supply is exhausted distend the cheeks again from the lungs. In this way the blast may be continued for several minutes, when necessary, without fatigue. If the blowpipe tip is in good condition the flame will be smooth, steady, and silent (Fig. 2–6).

2. Flames. A candle flame or luminous gas flame consists of 3 concentric parts (Fig. 1): (*a*) an inner cone of unburned gases; (*b*) a luminous mantle full of glowing particles of carbon, where carbon monoxide (CO) and water (H_2O) are forming by combustion; (*c*) a hot, non-luminous mantle of the products of complete combustion, carbon dioxide (CO_2) and water (H_2O) mingling with the surrounding air, and hence with an excess of oxygen. Hot fuel is in excess in (*b*), hence it is reducing in its action; the excess of oxygen makes (*c*) oxidizing. A non-luminous Bunsen or alcohol flame differs only in lacking the incandescent carbon in (*b*).

In determinative mineralogy these flames are often directed laterally or inclined downward by the use of the blowpipe. For oxidizing effects the tip should be inserted slightly into the flame, as in Fig. 2, thereby mixing more oxygen with the

gases at the base. The best reducing effect is obtained by withdrawing the tip a little from the flame and blowing very gently (Fig. 3). The flame should not be sooty, but a little luminous carbon should extend down the whole length of it.

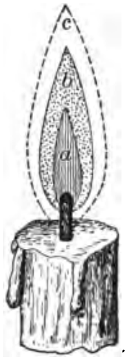

FIG. 1.

FIG. 2.

FIG. 1.—Candle flame: (*a*) Unburned gases; (*b*) burning gases, forming H_2O, CO, and luminous C; (*c*) hot combustion products, H_2O, CO_2, and O from surrounding air.

FIG. 2.—Blowpipe flame: (*b*) Intense heat and slightly reducing; (*c*) and beyond, oxidizing flame (o.f.).

3. Ignition: Fusion. The hottest flame is entirely non-luminous and the hottest part of it is just beyond the tip of the blue. The fusibility of a mineral is tested by strongly heating at this point an elongated fragment not more than 1.5 mm. ($\frac{1}{16}$ of an inch) in thickness; that is, no thicker than the "lead" of an ordinary pencil. This is held in the forceps so that it projects into the flame (Fig. 4). The mineral may fuse quietly, or with intumescence (bubbling and swelling up), or with exfoliation (splitting into leaves or flakes). The result may be a bead of colored or colorless glass, clear or filled with

bubbles; or it may be a white, opaque enamel. If infusible the mineral may remain unchanged, or it may change color,

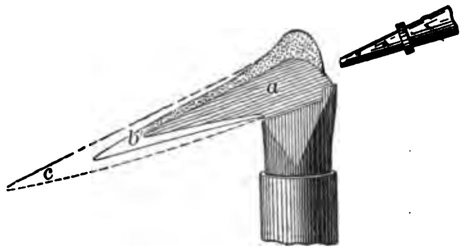

FIG. 3.—Blowpipe flame: (*b*) Strong reducing flame (r.f.), with more gas than used in o.f. and gentle blast.

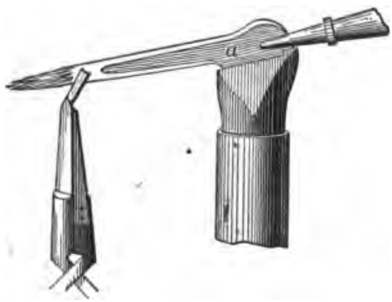

FIG. 4.—Testing fusibility, showing maximum size of fragment, manner of holding it, and position in the flame.

or become opaque, etc. All of these properties should be carefully noted.

The test of fusibility may be interfered with by *decrepitation*—the violent breaking away of particles with little crackling

explosions owing to sudden unequal heating or to the expansion of minute inclusions of water or liquid carbon dioxide. By first heating the mineral very gradually and gently in the ordinary flame this difficulty may sometimes be avoided; otherwise heat a few fragments in a closed tube until decrepitation ceases and select a fragment of suitable size if such remains. When this fails make a thin paste of the finely powdered mineral with water, spread a little of this on charcoal and heat, at first very gently, then intensely. The crust thus formed can be taken up carefully in the forceps and tested for fusibility.

4. Scale of Fusibility. The degree of fusibility of minerals is indicated by numbers referring to the following scale. Minerals named in parentheses have about the same fusibility as the standard. Comparison should be made on fragments of about the same size. Penfield recommends a standard size of about 1.5 mm. in diameter, as explained above. With the more difficultly fusible minerals, however, a much smaller fragment with a very thin edge or fine point should be tested before deciding that it is infusible.

SCALE OF FUSIBILITY

(Penfield's modification of von Kobell's scale)

1. *Stibnite*, Sb_2S_3. Fragments larger than standard size fuse easily in a luminous flame; fuses easily in closed tube below red heat. (Realgar, orpiment, sulphur.)

2. *Chalcopyrite*, $CuFeS_2$. Standard size fragment fuses in luminous flame; small fragment fuses in closed tube at red heat. (Galena, arsenopyrite, apophyllite.)

3. *Almandite* (Garnet), $Fe_3Al_2(SiO_4)_3$. Standard fragment fuses readily to globule with blowpipe; only thinnest edges rounded in luminous flame. (Malachite, wernerite, stilbite.)

4. *Actinolite*, $Ca(Mg,Fe)_3(SiO_3)_4$. Edges easily rounded on standard fragment; fine splinter fuses easily to globule. (Tremolite, wollastonite, barite.)

5. *Orthoclase*, $KAlSi_3O_8$. Edges of standard fragment rounded with difficulty; only finest splinters fuse to globule. (Sphalerite, biotite, scheelite.)

6. *Bronzite*, $(Mg,Fe)SiO_3$. Only finest points and thinnest edges can be rounded at all. (Enstatite, calamine, serpentine.)

5. Flame Color. On ignition in the forceps, and sometimes also on the charcoal, a distinct color may be imparted to the flame by the volatilization of a minute quantity of the mineral. The color is seen best against a dark background, such as a piece of charcoal or a book cover, or in a dark room. It is often more distinct when a trace of the fine powder is introduced into the flame with a clean platinum wire. (To clean the wire, heat it in the flame or boil in concentrated acid, if necessary, until it ceases to give a color to the flame.) The dry wire is dipped into the powder and then held in the flame. If the wire is first moistened with water a larger quantity of the powder will adhere and in some cases a better color is obtained. Dilute hydrochloric acid instead of water is sometimes an advantage.

FLAME COLORS

(For abbreviations, see page 60)

Color.	Shade.	Element.	Remarks.
Yellow	Intense	Na	Must be intense and persistent to indicate Na Invisible through dark blue glass
Red	Yelh. to orange	Ca	Often improved by moistening with HCl Green through green glass
Red	Crimson	Sr	Alkaline after ignition; so is Ca, but not Li Faint yellow through green glass
Red	Crimson	Li	Not alkaline after ignition; compare Sr Invisible through green glass
Green	Yellowish	Ba	Alkaline after ignition
Green	Yelh., pale	Mo	Not alkaline after ignition
Green	Bright, somewhat yelh.	B	Rarely alkaline after ignition. Test with turmeric paper and HCl sol. decisive
Green	Emerald	CuO,CuI	Blue, tinged with green, if moistened with HCl
Green	Pale	Te,Sb,Pb	
Green	Pale bluish	P	Often improved by moistening with conc. H_2SO_4
Green	Bluish	Zn	Usually streaks in outer part of flame
Blue	Greenish	P,Sb	
Blue	Azure	$CuCl_2$	Outer parts tinged emerald-green
Blue	Azure	Se	With characteristic radish-like odor
Blue	Pale azure	Pb	Green tinge in outer part of flame
Blue	Pale	As	
Violet	Pale	K	Purplish red through blue glass

6. On Charcoal. The length of the coal should be held in line with the flame, in order to catch any sublimate that may form; it should be also tilted toward the flame (Fig. 5). First burn a small spot on the coal with the oxidizing flame and note the color and appearance of the ash, in order to avoid confusing it with sublimates when making tests.

A slight depression is cut in the charcoal near one end and 3 or 4 grains of the mineral (not larger than pin heads), or a corresponding amount of fine powder, placed in it. In general a gentle oxidizing flame is blown first (Fig. 6), but only for a few seconds, not allowing the blue flame to touch the mineral. Any decrepitation or deflagration (flashing like gunpowder) is noted. Odors should be sought the moment the heat is stopped, and any change in color, formation of sublimate, metal globules, or magnetic particles, observed. The oxidizing flame is then repeated with greater intensity until reaction ceases. A similar method is followed with the reducing flame (Fig. 5), and in many cases the reaction is facilitated by fusing the powered mineral with three times its volume of soda, or a mixture of soda and borax, or of soda and powdered charcoal.

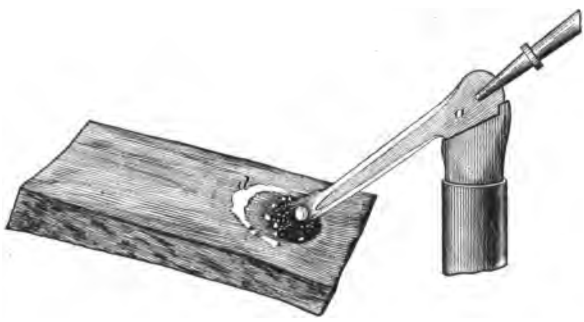

FIG. 5.—Reduction on charcoal, with sublimates (when formed) at (*d*) and beyond.

SUBLIMATES ON CHARCOAL

(For abbreviations, see page 60)

Near Assay.	Dist. from Assay.	Substance.	Remarks.
White, very volatile	Wh. to grayish	As_2O_3	Mostly far from assay; often strong garlic odor
Dense wh., volatile	Gray or slightly brownish	White, TeO_2 Gray, Te	Volatilizes in r.f., coloring flame pale green
Dense wh., volatile	Bluish	Sb_2O_3 and $SbSbO_4$	Heavy near the assay
White	White to bluish	Chlorides of Cu, Pb, Hg, NH_4, and alkalis	
Pale yel. to wh. hot; wh. cold: non-vol. in o.f.	Faint white	SnO_2	Moistened with $Co(NO_3)_2$ and ignited, subl. becomes bluish-green
Pale yel. hot; wh. cold; vol. in o.f.	Bluish	MoO_3	Touched with r.f., subl. becomes azure-blue. Cu-red MoO_2 subl. next to assay
Canary-yel. hot; wh. cold; non-vol. in o.f.	Faint white	ZnO	Moistened with $Co(NO_3)_2$ and ignited the subl. becomes green
Yel. hot; pale yel. cold; vol. in o.f. and r.f.	Dense white with bluish-wh. border	PbO $PbSO_3$ $PbSO_4$	Forms when galena and other Pb sulphides are heated very hot on charcoal
Dark yel. hot; S-yel. cold; vol. in o.f. and r.f.	Bluish-white	PbO	Heated with "bismuth flux" forms volatile yelh.-grn. subl., PbI_2
Dark orange-yel. hot; orange-yel. cold; vol. in o.f. and r.f.	Greenish-white	Bi_2O_3	Fused with "bismuth flux" in small o.f. forms yel. subl. fringed by brilliant red
Nearly blk. to rdh.-brn.; vol. in o.f. and r.f.	Yellow	CdO	Iridescent when very thin
Rdh. to deep lilac		Ag with Pb and Sb	Ag alone gives slight bnh. subl. after long ignition
Copper-red	White	MoO_2, MoO_3	Touched with r.f., white subl. becomes azure-blue
Steel-gray, faint metallic luster; very vol.	White; may be tinged red	White, SeO_2 Red, Se	Subl. colors r.f. azure-blue. Characteristic radish-like odor

7. Roasting. Spread a fine powder of the mineral thinly on charcoal and heat with a small oxidizing flame, a considerable distance beyond the tip of the blue and at no more than a dull red heat (Fig. 6). If the mineral fuses easily heat intensely till the volatile constituents are driven off, then pulverize with a little powdered charcoal and repeat the roasting with the mixture, using the small oxidizing flame and low temperature again.

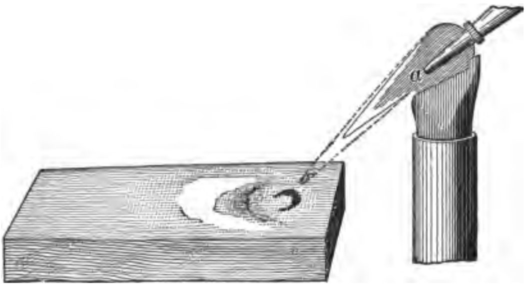

FIG. 6.—Roasting on charcoal; very small o.f., scarcely red heat.

8. On Gypsum Tablets. The tablet may be held in the same manner as the charcoal, or may be placed on charcoal as a support. A little of the pulverized mineral is fused with "bismuth flux" near one end of the tablet. Volatile iodides of the metals are formed, many of which produce characteristic sublimates on the cool part of the gypsum. The same process may be used on charcoal, and in the following table the results are compared with those on gypsum.

9. In Closed Tube. The object is to heat the mineral with little air, and hence with little oxidation. Use small fragments; fine powder adheres to the side of the tube and may interfere with sublimates. Volatile emanations that give an odor or condense as a sublimate or a liquid on the side of the tube are to be specially noted; also decrepitation, phosphorescence, fusion, change in form or color, or magnetism. The upper end of the

IODIDE SUBLIMATES ON GYPSUM AND CHARCOAL

(For abbreviations, see page 60)

On Gypsum.	Substance.	On Charcoal.
Chrome-yel., volatile	PbI_2	Chrome-yel.; gnh. if thin; volatile
Yel. to orange; very volatile	AsI_3	Faint yellow
Orange to red; disappears in strong ammonia fumes	SbI_3	Faint yellow
Scarlet with yel.; if strongly heated is dull yel. and blk.	HgI	Faint yellow
Brownish-orange	SnI_4	White
Rdh.-brn., nearly scarlet	SeI_4	Does not show on charcoal
Chocolate-brn., with underlying scarlet; in ammonia fumes becomes orange and then cherry-red	BiI_3	Bright red; yel. near assay
Purplish-brn., darker border	TeI_4	Does not show on charcoal
Ultramarine-blue, deep	MoI_4	Does not show on charcoal

tube must be kept cool, and this is best assured by holding it only with the fingers and keeping it nearly horizontal (Fig. 7).

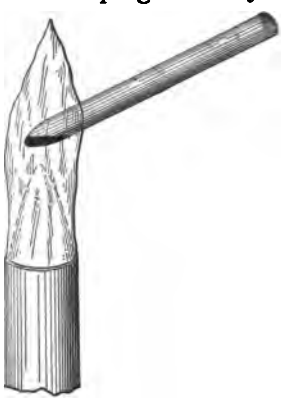

FIG. 7.—Heating in closed tube (c.t.): Hold the tube with the fingers only.

SUBLIMATES IN CLOSED TUBE

(For abbreviations, see page 60)

Hot.	Cold.	Substance.	Remarks.
Cols. liquid; easily vol.	Cols. liquid	H_2O	Neutral or acid; rarely alkaline
White solid	White solid	$PbCl_2$, $SbCl_3$, As_2O_3, Sb_2O_3, NH_4 salts	
Gray metallic liquid globules		Hg	Unite by rubbing with strip of paper
Pale yel. to cols. liquid; difficultly volatile	Cols. to wh. globules	TeO_2	From Te and some compounds
Dark yel. to red liquid; easily volatile	Yel. xln. solid; pale in small amt.	S	From S and some sulphides
Dark red liquid, nearly blk.; easily volatile	Rdh.-yel. transparent solid	AsS As_2S_3	From sulphides and sulpharsenites
Blk. solid; dif. vol.	Rdh.-brown	Sb_2OS_2	Sulphides and sulphantimonites
Brilliant blk. solid; often gry. and xln. near heated end		As	From As and arsenides. Break off closed end and heat subl. for garlic odor
Brilliant blk. solid	....	HgS	Subl. rubbed gives red powder
Blk. fusible globules	....	Te	Te and tellurides; usually some TeO_2 formed (see above)
Blk. fusible globules; smallest deep red by transmitted light		Se	Often also wh. xln. SeO_2

10. In Open Tube. The object is to heat the mineral with a good supply of air for oxidation. Place finely powdered mineral near one end of the tube (at the elbow if the tube is bent). Hold the tube steeply inclined, with the pow-

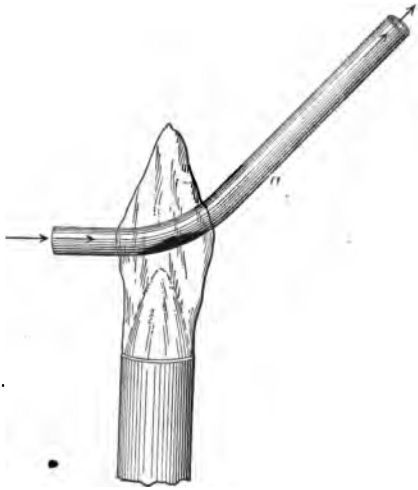

FIG. 8.—Heating in open tube (o.t.): Use tube holder and heat first at (*a*) to insure draft.

der at the lower end, using a holder, since the whole tube will become hot. First heat the tube well just above the mineral (at *a*, Fig. 8) so as to insure a good draft, then bring the mineral over the flame.

SUBLIMATES IN OPEN TUBE

(For abbreviations, see page 60)

Color and Character.	Substance.	Remarks.
Wh. xln., readily volatile	As_2O_3	Xln. (octahedrons) on the warm glass
Wh. xln., readily volatile	SeO_2	Us. rad. xls.; often a little red S
Wh. xln., slowly volatile	Sb_2O_3	Xls. are octahedrons and prisms
Wh. non-vol., infusible	$PbSO_3$ $PbSO_4$	Slight deposit; mostly on lower side of tube near assay
Wh. to pale yel. globules; slowly vol.	TeO_2	
Pale yel. hot; wh. cold; amorph., infus., non-vol.	$SbSbO_4$	Dense wh. smoke; subl. mostly on under side of tube; us. some volatile Sb_2O_3
Pale yel. hot; wh. cold; fus. and vol. at red heat	MoO_3	Network of delicate xls. near assay
Yel. to orange; easily vol.	S, AsS	These sublimates result from too rapid heating; will not form with proper draft and oxidation. Heat tube above assay first, then directly under it
Blk. hot; brn. cold; dif. volatile	Sb_2OS_2	
Brilliant blk.; volatile	As,HgS	
Gry. metallic globules; volatile	Hg	Unite by rubbing with strip of paper
Red, volatile	Se	Often with white SeO_2 (see above)

11. In Borax Bead. A round loop ($\frac{1}{8}$ inch diameter) of platinum wire may be made conveniently by bending it around the tapering part of a pencil near the point (Fig. 9*a*). The loop is heated in the Bunsen or blowpipe flame and dipped into the powdered borax. The part that adheres is fused to a clear globule (Fig. 10); this is again dipped into the borax, and the process is repeated until a nearly spherical bead is obtained. The hot bead is touched lightly to a fine powder of the mineral and is then heated thoroughly in the

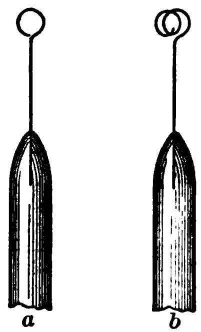

FIG. 9.—Platinum wire loops: (*a*) Single loop $\frac{1}{8}$ inch, for bead tests; (*b*) double loop, holding larger quantity, for decomposing insoluble minerals in fluxes.

oxidizing flame. The degree of solubility of the particles and the colors, if any, imparted to the bead are carefully noted. It is then heated continuously for some time in the reducing flame, and any change noted. The quantity of the powdered mineral in the bead is gradually increased until a distinct reaction is obtained or until the bead is saturated with it.

Precaution. Sulphides, arsenides, antimonides, etc., must first be thoroughly roasted at a dull red heat (Fig. 6), as directed in Section 7, page 14, in order to convert them into oxides; otherwise no characteristic reaction will occur.

BORAX BEAD REACTIONS

(For abbreviations, see page 60)

(M indicates medium amount; + indicates much; – indicates little)

Oxidizing Flame.		Reducing Flame.		Amount.	Oxide of
Hot.	Cold.	Hot.	Cold.		
Colorless	Colorless	Colorless	Colorless	+ or –	Si, Al, Sn
Colorless	Cols. or opaq. wh.	Colorless	Cols. or opaq. wh.	+ or –	Ca, Sr, Ba, Mg, Zn, Zr, Cb
Pale yel.	Cols. or wh.	Pale yel.	Colorless	+	Pb, Sb, Cd
Pale yel.	Cols. or wh.	Gray	Gray	+	Bi
Pale yel.	Cols. or wh.	Brown	Brown	+	Mo
Pale yel.	Cols. or wh.	Yellow	Yel. to yelh-brn.	M	W
Pale yel.	Cols. or wh.	Grayish	Bnh.-violet	M	Ti
Yellow	Nearly cols.	Pale green	Nearly cols.	–	Fe, U
Yellow	Yelh.-green	Green	Green	–	Cr
Yellow	Pale yelh.-grn.	Dirty grn.	Fine green	–	V
Yel. to orange	Yellow	Pale green	Pale grn. to nearly cols.	M to +	U
Yel. to orange	Yellow	Bottle grn.	Pale green	M to +	Fe
Yel. to orange	Yelh.-grn.	Green	Green	M to +	Cr
Green	Blue	Cols. to grn.	Opaq. red (+)	– to M	Cu
Blue	Blue	Blue	Blue	– to M	Co
Violet	Rdh.-brn.	Opaq. gray	Opaq. gray	– to M	Ni
Violet	Rdh.-violet	Colorless	Colorless	–	Mn

12. In Sodium Metaphosphate Bead. The bead is made by heating sodium ammonium phosphate on a loop of platinum wire in the same manner as previously described for the borax bead; but when first fused it is much more liquid than borax and considerable care must be exercised in order to avoid

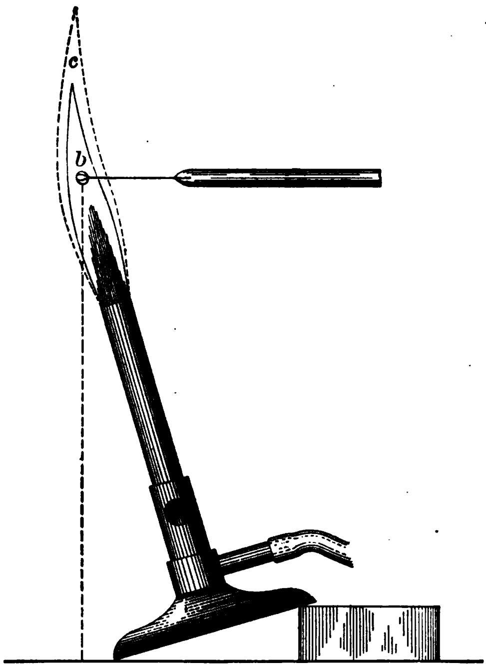

FIG. 10.—Making a bead in the Bunsen flame. If the bead drops it falls clear of the burner instead of clogging it. This position is specially important for sodium metaphosphate (s.ph.) beads.

dropping it. It is best to tilt the burner at a considerable angle (Fig. 10), so that beads cannot drop into it and clog it. Hold the wire over the center of the flame, with the circular loop horizontal. Do not undertake to fuse much of the salt

SODIUM METAPHOSPHATE BEAD REACTIONS

(For abbreviations, see page 60)

(M indicates medium amount; + indicates much; − indicates little)

Oxidizing Flame.		Reducing Flame.		Amount.	Oxide of
Hot.	Cold.	Hot.	Cold.		
Colorless	Cols. or opaq. white	Colorless	Cols. or opaq. white	− or +	Ca, Sr, Ba, Mg, Zn, Al, Zr, Sn, Si (Si nearly insol.)
Pale yel.	Colorless	Pale yel.	Colorless	+	Cd
Pale yel.	Colorless	Gray	Gray	+	Pb, Sb, Bi
Pale yel.	Colorless	Brown	Brown	+	Cb
Pale yel.	Colorless	Dirty blue	Fine blue	M	W
Pale yel.	Colorless	Yellow	Violet	− to +	Ti
Yellow	Colorless	Pale yelh.-grn.	Colorless	−	Fe
Yellow	Pale grnh.-yel.	Pale grn.	Fine grn.	M	U
Yelh.-grn.	Colorless	Dirty grn.	Fine grn.	M	Mo
Yel. to bnh.-red	Yel. to cols.	Red, yel., to yelh.-grn.	Nearly cols. to pale violet	M to +	Fe
Yel. to deep yel.	Yellow	Dirty grn.	Fine grn.	− to M	V
Red to bnh.-red	Yel. to redh.-yel.	Red to bnh.-red	Yel to redh.-yel.	− to M	Ni
Green	Pale blue	Pale yelh.-grn.	Pale blue, nearly cols.; at times ruby-red	−	Cu
Dark green	Blue	Bnh.-grn.	Opaq. red	M	Cu
Dirty grn.	Fine grn.	Dirty grn.	Fine grn.	− to M	Cr
Blue	Blue	Blue	Blue	− to M	Co
Gryh.-violet	Violet	Colorless	Colorless	M	Mn

at a time, but build up the bead by small additions, heating each time until all bubbling stops. The salt fuses to sodium metaphosphate, $NaPO_3$, and is used in exactly the same manner as the borax bead.

13. In Sodium Carbonate Bead (Soda). The soda bead on platinum wire is opaque white when cold. It is prepared in the same manner as borax or s.ph. beads (see preceding sections), and is useful for the following reactions:

Manganese: in o.f., green when hot, blue when cold; in r.f., colorless.

Chromium: in o.f., yellow.

Quartz: in fine powder fused with about equal volume of soda gives a clear glass.

14. With Acids. For most purposes dilute hydrochloric acid is used; but for sulphides and arsenides, which require oxidation, nitric acid is best.

Usually the object of the first test with an acid is to determine whether the mineral is decomposed or dissolved by it. This is best done with a very small amount of the fine powder, just enough to be distinctly visible in the bottom of the test tube. Fill the tube with acid to a depth of $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. If no immediate reaction occurs, heat to boiling and observe any change, particularly whether any of the powdered mineral has disappeared. If the mineral seems unchanged continue the boiling for several minutes. If solution or any other reaction occurs, add a larger amount of the powdered mineral in order to get distinct results.

(1) Solution may occur with effervescence in cold acid or only on heating, with the evolution of CO_2, colorless and odorless, from carbonates; H_2S, colorless and disagreeable odor, from some sulphides; Cl, nearly colorless, pungent odor, bleaches moist litmus paper, from some higher oxides in HCl; NO_2, dark red vapors, when oxidation of sulphides, etc., takes place in HNO_3.

(2) Solution may take place without effervescence, giving a clear, colorless solution, without a residue. When slow this reaction is sometimes difficult to detect. After boiling with a large amount of the powdered mineral, evaporate a drop of the clear liquid on a watch glass or a piece of Pt foil (or a flake of mica, if HCl or HNO_3 is used). A residue indicates that some of the mineral has gone into solution.

(3) Solution may occur without effervescence and without residue, as in (2), but with a colored solution. Yellowish to brownish red, ferric iron minerals in HCl; green from nickel and from mixtures of copper and iron (the addition of ammonia to the solution gives blue with copper or nickel, very intense with the former); blue from copper, intensified by the addition of an excess of ammonia; pink or pale rose from cobalt minerals.

(4) Solution may occur without effervescence, leaving an insoluble residue. Gelatinous silica from some silicates, appears on evaporation of the acid; powdery or flaky silica separates from some silicates—it is more translucent than the finest powder of most minerals; white opaque metallic oxides, especially from Sn, Sb, and Pb minerals in HNO_3; yellow powder, WO_3, from some tungstates in HCl; yellow floating mass of sulphur, often black with particles of the mineral, from many sulphides in HNO_3.

15. With Coba t Nitrate. The solution is useful with light-colored infusible minerals. Heat a small amount of the fine powder or minute fragments intensely on charcoal in the oxidizing flame; moisten the mineral with the solution, and again ignite to an intense white heat. Distinct colors may be imparted, as follows:

Blue, aluminum minerals, zinc silicates.

Bluish-green, tin oxide.

Yellowish-green, zinc and titanium oxides.

Dark green, oxides of antimony and cobalt.

Pink, usually pale, from magnesium minerals.

16. Precipitates from Solution. The following reagents are most commonly used. For distinctions between the various precipitates, see the tests for the elements on succeeding pages.

Ammonia precipitates hydroxides of Al, Gl, Bi, chromic Cr, Fe, Pb, Ti, and rare earth metals. (In the presence of phosphoric, arsenic, silicic, and hydrofluoric acids various other substances are also precipitated.)

Ammonium carbonate and *ammonium oxalate* precipitate Ca, Sr, and Ba from solutions made alkaline with ammonia.

Ammonium sulphide precipitates from neutral or alkaline solutions sulphides of Fe, Zn, Mn, Co, Ni, and hydroxides of Al, Cr, and rare earth metals.

Barium chloride precipitates $BaSO_4$ from acid solutions of a sulphate—a delicate test.

Hydrochloric acid precipitates chlorides of Ag, Pb, and mercurous Hg from solutions in HNO_3.

Silver nitrate precipitates silver chloride, bromide, or iodide from solutions of the corresponding minerals in water or HNO_3.

Sodium phosphate precipitates Mg from solutions in which ammonia and ammonium carbonate give no precipitates or in the filtrate after precipitating with these reagents.

Sulphuric acid precipitates sulphates of Pb, Ba, and Sr, and also Ca in concentrated solutions.

REACTIONS FOR THE ELEMENTS

(For list of elements, see page 58; abbreviations, page 60)

ALUMINUM (Al; trivalent; at.wt. 27.1)

(1) **Ign. with Cobalt Nitrate.** Fine powder of light-colored infus. Al minerals assume a fine blue color when moistened with the solution and intensely heated either on ch. or in a small loop of Pt wire. Zn silicates also give blue color, but will also yield test for Zn.

(2) **Precipitation with Ammonia.** Added in slight excess to acid solutions, gelatinous $Al(OH)_3$ is precipitated. To distinguish from other similar-looking precipitates obtained in the same way, filter, wash the ppt., place part of it in test tube with H_2O and KOH; if it is $Al(OH)_3$ it will go easily into solution. Burn the filter (in crucible or on ch.) and the rest of the ppt. will give foregoing test with cobalt nitrate.

For Al in silicates, see Silicon (2).

ANTIMONY (Sb; trivalent and pentavalent; at.wt. 120.2)

(1) **Oxide Subl. on ch.** Heat fragments on ch. in o.f. A dense white subl. of Sb_2O_3 forms very near the assay (compare As). Where thin the coating looks bluish. Subl. is volatile and may be driven about readily by the o.f. or r.f. No distinctive odor (compare As) unless S or As is present.

(2) **Antimonate Subl. in o.t.** When heated in o.t. most Sb sulphides yield a heavy white subl., $SbSbO_4$, along the

under side of the tube, which is non-vol. (compare As), straw-yel. when hot and white on cooling.

(3) **Oxysulphide Subl. in c.t.** On intense ign. sulphides yield a black subl. of Sb_2S_2O, rich redh.-brn. on cooling. Dif. vol.

(4) **Iodide Subl. on Gypsum.** Mixed with "bismuth flux" or moistened with HI and heated in o.f. on gypsum tablet, a red subl. of SbI_3, which disappears in fumes of strong ammonia.

(5) **Flame Color.** Sb volatilizes in r.f. and gives a pale greenish color to the flame. Pt forceps must not be used.

ARSENIC (As; trivalent and pentavalent; at.wt. 75)

(1) **Oxide Subl. on ch.** Metallic As, its sulphides and the arsenides when heated on ch. yield white fumes of a garlic-like odor and a white crystalline subl. of As_2O_3 far from the assay.

(2) **Oxide Subl. in o.t.** Subl. and odor like preceding are produced in the tube. Easily volatile and driven out of the tube.

(3) **Metallic Mirror in c.t.** The metal and some arsenides yield a brilliant black arsenical mirror. When abundant the part nearest the assay crystallizes and looks gray. By breaking off the closed end of tube and heating the subl. the garlic odor is produced. Oxygen compounds require powdered charcoal also in the c.t.

(4) **Iodide Subl. on Gypsum.** Powder mixed with "bismuth flux" or moistened with HI and heated in o.f. on gypsum tablet, a vol. orange-yel. subl. of AsI_3 forms.

(5) **Flame Color.** In r.f. As volatilizes and colors the flame violet.

Barium (Ba; bivalent; at.wt. 137.4)

(1) **Flame Color.** A gnh.-yel. color is imparted to the flame, sometimes intensified by moistening with HCl. Silicates do not give the flame color. Must be distinguished carefully from B and P flame colors.

(2) **Sulphate Precipitate.** A few drops of dilute H_2SO_4. give a white ppt. of $BaSO_4$ from solutions in water and dilute acids. A delicate test and distinguishes from B and P. Insoluble silicates require previous fusion of the finely powdered mineral with 3 volumes of soda in a loop of Pt. wire, which renders them soluble in HCl. Test ppt. for flame color using clean Pt wire. If both Ba and Sr are present a mixed flame results.

(3) **Alkaline Reaction.** Like the other alkaline earths and most alkalis, some Ba minerals give alkaline reaction on moist turmeric paper after ignition.

Bismuth (Bi; trivalent; at.wt. 208)

(1) **Metallic Bi and Oxide Subl. on ch.** Heat the mineral with 3 times its volume of soda on ch. Brittle metallic globules of Bi are obtained and a yellow coating of Bi_2O_3 which is white further away. Subl. much like that of Pb, but metal less malleable; distinguished by the following test.

(2) **Iodide Ppt. on ch. and Gypsum.** Mix the powdered mineral with " bismuth flux " or moisten with HI and heat in the o.f. on ch. The subl. is yellow near the assay and bordered by brilliant red BiI_3. On a gypsum plate the subl. is chocolate-brown but changes to a brilliant red on exposure to strong ammonia fumes.

BORON (B; trivalent; at.wt. 11)

(1) **Flame Color.** A somewhat yellowish-green (siskin-green) flame color. Must not be confused with Ba flame. Readily distinguished by other tests. Some B minerals require heating with 3 volumes of a mixture of $3KHSO_4$ and $1CaF_2$; the BF_2 formed gives a momentary color to the flame.

(2) **With Turmeric Paper.** Moisten turmeric paper with a dilute HCl sol. of the mineral and dry it on the outside of a test tube containing boiling water. The paper becomes reddish-brown; on moistening with ammonia it becomes black. Insol. minerals must first be fused in fine powder with 3 volumes of soda on a loop of Pt wire and then dissolved in HCl.

BROMINE (Br; univalent; at.wt. 79.9)

(1) **Precipitation as Bromide.** Solutions of bromides in water or dilute HNO_3 yield a white ppt. of AgBr when $AgNO_3$ is added.

(2) **Pb Bromide Subl. in c.t.** AgBr heated in c.t. with galena (PbS) yields a subl. of $PbBr_2$, which is S-yellow while hot and white when cold.

CADMIUM (Cd; bivalent; at.wt. 112.4)

(1) **Oxide Subl. on ch.** Heated on ch. with 3 volumes of soda, metallic Cd is volatilized and sublimed as reddish-brown CdO, which is yellow distant from the assay and iridescent if only a little forms.

CALCIUM (Ca; bivalent; at.wt. 40.1)

(1) **Flame Color.** Some Ca minerals give yelh.-red color to the flame (green through green glass), often strengthened by moistening with HCl. Must not be confused with the much redder Sr and Li flames.

(2) **Sulphate ppt.** A few drops of dilute H_2SO_4 added o an HCl sol. of a Ca mineral precipitates white $CaSO_4 \cdot 2H_2O$, which goes into solution on addition of water and boiling. This sol. in water distinguishes it from Sr and Ba.

(3) **Carbonate or Oxalate ppt.** Ammonium carbonate or oxalate added to a solution made strongly alkaline with ammonia forms a white ppt. of the corresponding Ca compound. The oxalate is also formed in slightly acid solutions and this test can be applied in solutions of phosphates, silicates, and borates, which cannot be made alkaline with ammonia without precipitating Ca salts.

(4) **Alkaline Reaction.** Like other alkaline earths and most of the alkalis, some Ca minerals give an alkaline reaction on moist turmeric paper after ignition.

For Ca in silicates, see Silicon (2).

Carbon (C; tetravalent; at.wt. 12)

(1) **Odor in c.t.** The characteristic empyreumatic odor of distilling organic substances is given in c.t. by hydrocarbons and bituminous coal. Anthracite does not yield it, but is combustible in the o.f.

(2) **CO_2 from Carbonates.** Heat fragments of the mineral in the c.t. held horizontally with a drop of $Ba(OH)_2$ in the open end of the tube; the latter is clouded with a white ppt. of $BaCO_3$.

(3) **Effervescence with Acids.** Treat the powdered mineral with dilute HCl, HNO_3, or H_2SO_4, and warm if necessary. Guard against mistaking boiling for effervescence. Tip the test tube gently and pour accumulated CO_2 (gas) into another tube containing $Ba(OH)_2$; on shaking the latter a white ppt. of $BaCO_3$ forms. Concentrated acids do not yield the test unless the salts formed are soluble in the acids.

CHLORINE (Cl; univalent; at.wt. 35.5)

(1) **Flame Color with CuO.** Mix powdered mineral with CuO and moisten with H_2SO_4, dry gently on ch. and ignite. Or saturate a small s.ph. bead with CuO, add a fragment of the mineral and heat in the o.f. In either case the azure-blue flame of $CuCl_2$ will appear. Br gives a similar reaction.

(2) **Evolution of Cl.** A powdered chloride heated in a small test tube with a little pyrolusite (MnO_2) and 4 times its volume of $KHSO_4$ gives off Cl gas, which is recognized by its pungent odor and its bleaching effect on a piece of moist litmus paper placed inside the tube. AgCl and silicates containing Cl require fusion first with 3 volumes of soda.

(3) **AgCl ppt.** From a solution of a chloride in water or dilute HNO_3 a few drops of $AgNO_3$ sol. ppts. white AgCl, curdy if abundant, bluish opalescent if little. Br and I give similar reactions. Light soon changes color of the ppt. to violet. Insoluble minerals must first be fused with 3 volumes of soda.

(4) **Sublimate with Galena.** To distinguish chloride, bromide, and iodide of Ag, heat in c.t. with powdered galena. A subl. of $PbCl_2$ forms colorless globules which are white when cold; $PbBr_2$ is S.-yel. hot and white when cold; PbI_2 is dark orange-red hot and lemon-yellow cold. The presence of Br obscures that of Cl and I obscures both of the others.

CHROMIUM (Cr; trivalent and sexivalent; at. wt. 52)

(1) **Borax Bead Reac.** In o.f. yellow hot (red with much), yel.-grn. cold. In r.f. green hot and cold.

(2) **S.ph. Bead Reac.** In o.f. dirty green hot, clear green cold. In r.f. similar colors but weaker. V differs in giving yellow color to s.ph. bead in o.f.

(3) **Soda Bead Reac.** In o.f. dark yellow while hot, light yellow and opaque cold; in r.f. yelh.-green opaque when cold.

COBALT (Co; bivalent; at.wt. 59)

(1) **In Borax and s.ph. Beads.** Fine blue in both o.f. and r.f. When Cu or Ni interferes remove the bead from the Pt wire and fuse it on ch. with a granule of Sn and the Co color will appear.

COLUMBIUM (Niobium) (Cb; pentavalent; at.wt. 93.5)

(1) **Reduction in Solution.** Mix powdered mineral with 5 volumes of borax, moisten to a paste with water and fuse in a double loop of Pt wire (Fig. 9*b*). Crush 2 or 3 such beads to powder and boil with HCl to a clear solution. Add Sn and boil and the sol. becomes blue, which changes slowly to brown on continued boiling and disappears on dilution. With Zn instead of Sn the blue color changes quickly to brown. W gives similar tests, but other tests for that element will distinguish.

COPPER (Cu; bivalent and univalent; at.wt. 63.6)

(1) **Flame Color.** The oxide and oxidized sulphides give an emerald-green color. When moistened with HCl the flame is azure-blue. The same result is obtained by adding a grain of common salt, NaCl, to a s.ph. bead saturated with the substance.

(2) **Metallic Cu on ch.** Oxides, and sulphides that have been previously roasted, yield globules of red malleable Cu when fused on ch. with 3 volumes of a flux of equal parts of soda and borax in r.f.

(3) **Borax and s.ph. Bead Reactions.** In o.f. green hot and blue cold; in r.f. pale with little Cu, red and opaque with much.

(4) **Color in Solution.** Blue or green sol. in HNO_3 or HCl, made deep blue by adding ammonia in excess. Ni gives a much fainter blue by similar treatment.

FLUORINE (F; univalent; at.wt. 19)

(1) **HF in c.t.** Mix the finely powdered mineral with an equal volume of powdered glass, and 3 volumes of $KHSO_4$ and heat gently in c.t. The HF liberated attacks the glass and forms SiF_4, which decomposes to H_2SiF_6 with separation of SiO_2; this forms a volatile white subl. in the tube. Break off bottom of tube, wash subl. with water and dry; the remaining subl., SiO_2, is non-vol.

(2) **Etching Glass.** Mix powdered mineral with a few drops of conc. H_2SO_4 and spread over a glass that has been previously coated with paraffin and scratched with a pointed instrument. Let stand 5 minutes or longer. Wash off the acid, warm the glass, and wipe off paraffin to observe etching.

(3) **With $NaPO_3$ in c.t.** Mix the powdered mineral with 5 times the volume of powdered s.ph. beads and heat very hot in c.t. A subl. forms as in (1) and may be tested as there described.

GOLD (Au; univalent and trivalent; at.wt. 197.2)

(1) **Metal with Soda on ch.** The color, fusibility, malleability, and insolubility in any single acid serve to distinguish it from other metals.

HYDROGEN (H; univalent; at.wt. 1)

(1) **Water in c.t.** Minerals containing hydroxyl, acid hydrogen, or water of crystallization, when heated in c.t. give off water which condenses in the cold part of the tube. Hydroxyl and acid H require high temperature. Some salts of

weak bases yield acid water and from some ammonia compounds it is alkaline, as shown by a strip of red litmus paper inserted in the tube.

IODINE (I; univalent; at.wt. 126.9)

(1) **Iodide Subl. with Galena.** Heat the powdered mineral with powdered galena in c.t.; a subl. of PbI_2 is formed which is dark orange-red while hot and lemon-yellow when cold.

(2) **Ppt. with $AgNO_3$.** From dil. HNO_3 solution $AgNO_3$ ppts. white AgI, which differs from AgCl and AgBr in being nearly insoluble in ammonia.

(3) **I with $KHSO_4$.** Violet I vapor is formed when iodides are heated in c.t. with $KHSO_4$.

IRIDIUM (Ir; trivalent and tetravalent; at.wt. 193.1)

One of the rare Pt metals. See Platinum.

IRON (Fe; bivalent and trivalent; at.wt. 55.8)

(1) **Magnetism.** A few Fe minerals are magnetic and many become so on heating in r.f. (or roasting and then heating in r.f. in case of sulphides and arsenides). The test is more delicate if the powder is fused with a little soda, giving a magnetic slag. In all cases only the cold material is magnetic.

(2) **Borax Bead Reac.** With small amount of mineral the bead in o.f. is yellow hot and nearly colorless cold; with much it is bnh.-red hot and yellow cold. With little in r.f. it becomes pale green hot and colorless cold; with much it is bottle-green hot and paler when cold. With sulphides and arsenides the bead test can be made only after roasting.

(3) **Hydroxide ppt.** When ammonia is added to a dil. HNO_3 sol. or to HCl sol. which has been boiled with a few drops of HNO_3, a bnh.-red ppt. of $Fe(OH)_3$ is formed. In

ferrous HCl sol. ammonia gives a dirty green $Fe(OH)_2$ ppt. which slowly turns brown by oxidation.

(4) **Ferrous and Ferric Fe.** In cold dilute acid solutions potassium ferricyanide, $K_6Fe_2(CN)_{12}$, gives a dark blue ppt. with ferrous Fe; in ferric solutions it deepens the color but gives no ppt. Potassium ferrocyanide, $K_4Fe(CN)_4$, gives a dark blue ppt. with ferric solutions; from ferrous sol. it gives a pale bluish-white ppt. which rapidly becomes blue. NH_4CNS or KCNS gives a dark red color to ferric solutions.

Minerals insol. in acids must first be fused in c.t. with 3 volumes of borax glass (powdered borax beads). Break off lower end of tube and boil in a little HCl for a minute; dilute the sol., divide it into two parts, and test as above for ferrous and ferric Fe.

For Fe in silicates, see Silicon (2).

Lead (Pb; bivalent and tetravalent; at.wt. 207.1)

(1) **Metal and Subl. on ch.** Mix 1 part powdered mineral, 1 part powdered charcoal, and 3 parts soda, moisten and fuse in r.f. on ch. Globules of soft, malleable, and sectile metal form, bright in r.f. and dull on cooling; also subl. of PbO, yellow near assay, bluish-white further away.

(2) **Iodide Subl. on ch.** Heat powdered mineral with 3 volumes of "bismuth flux" in o.f. on ch. A chrome-yel. subl. of PbI_2 forms near and greenish-yellow far from assay.

(3) **Ppts. from Solution.** From solution in dil. HNO_3 either H_2SO_4 or HCl forms a white ppt. ($PbSO_4$ or $PbCl_2$). From a boiling solution of the mineral in HCl white $PbCl_2$ crystallizes out on cooling.

Lithium (Li; univalent; at.wt. 6.9)

(1) **Flame Color.** Crimson flame when heated in Pt forceps or from powdered mineral on clean Pt wire (invisible

through green glass). For silicates better results are obtained by mixing the mineral with equal parts of powdered gypsum. Flame color is much like that of Sr, but redder than that of Ca. Compare Sr and Ca.

MAGNESIUM (Mg; bivalent; at.wt. 24.3)

(1) **Color with Cobalt Nitrate.** Some light-colored Mg minerals become pale pink when strongly ignited after moistening with $Co(NO_3)_2$ sol.

(2) **Alkaline Reac.** Some Mg minerals give alkaline reac. on moist turmeric paper after ignition, like the alkalis and alkaline earths, but weaker, and less decisive.

(3) **Ppt from Solution.** If HCl sol., boil with a drop of nitric acid, make strongly alkaline with ammonia, and remove Fe, Al, and Ca by successive precipitation with ammonia and ammonium oxalate, filtering each time a precipitate appears. To the clear filtrate add sodium phosphate and a crystalline ppt. of $NH_4MgPO_4 \cdot 6H_2O$ appears.

For Mg in silicates, see Silicon (2).

MANGANESE (Mn; bivalent, trivalent, tetravalent; at.wt. 54.9)

Minerals containing S, As, etc., must be roasted in o.f. before making bead tests.

(1) **Soda Bead Reac.** In o.f. green while hot, bluish-green cold; in r.f. white.

(2) **Borax Bead Reac.** In o.f. opaque while hot, reddish-violet when cold, black if too much is used. In r.f. colorless. Similar results in s.ph. but not so delicate.

(3) **Evolution of Cl.** Higher oxides of Mn decompose HCl with evolution of Cl gas.

MERCURY (Hg; univalent and bivalent; at.wt. 200)

(1) **Metal in c.t.** Mix the powdered mineral with 4 volumes of soda that has been dried by heating nearly to redness on clean metal or in a procelain crucible; put mixture in c.t., cover with dry soda, and heat gradually. Hg appears as gray subl. or as globules on the walls of the tube. Alone in c.t. most Hg compounds volatilize without decomposing. Cinnabar gives a black subl. like the As mirror.

(2) **Hg Ppt. on Cu.** Clean Cu in a Hg sol. receives a coating of metallic Hg, giving the appearance of silver plating.

MOLYBDENUM (Mo; tetravalent and sexivalent; at.wt. 96)

(1) **Subl. in o.t.** Thin flakes of molybdenite at a high temperature in o.t. give a yellow subl. of MoO_3, frequently also delicate crystals.

(2) **Flame Color.** At tip of blue flame gives a pale yelh.-green color.

(3) **S.ph. Bead Reac.** With a small amount of the oxide in o.f. the bead is yelh.-green while hot, nearly colorless cold; in r.f. dirty green hot, fine green on cooling.

(4) **Color in Sol.** Place finely powdered mineral with a minute scrap of paper (about 1 mm. square) in a test tube with a few drops of water and an equal quantity of conc. H_2SO_4; heat till copious acid fumes form, let cool, and add water, one drop at a time. A deep blue color appears and quickly disappears with much dilution.

NICKEL (Ni; bivalent; at.wt. 58.7)

(1) **Borax Bead Reac.** In o.f. violet while hot, redh.-brown cold; opaque by long heating in r.f. On ch. with Sn the

bead becomes colorless. Co in small amt. obscures the bead test for Ni.

(2) **Color of Sol. and Ppt.** Sol. in HNO_3 is apple-green; becomes blue with ammonia. Compare the much deeper blue with Cu from this treatment.

NITROGEN (N; trivalent and pentavalent; at.wt. 14)

(1) **Deflagration on ch.** Nitrates deflagrate (flash somewhat like gunpowder) upon ignition on ch.

(2) **Fumes in c.t.** Heat mineral powder in c.t. with $KHSO_4$. NO_2 fumes given off are recognized by red color on looking into the end of the tube.

OSMIUM (Os; bivalent, tetravalent, etc.; at.wt. 190.9)

One of the rare platinum metals. See Platinum.

OXYGEN (O; bivalent; at.wt. 16)

(1) **O gas in c.t.** Some higher oxides give off O when heated in c.t. A glowing stick inserted will burn brightly.

(2) **Cl Gas with HCl.** Some higher oxides decompose HCl with the liberation of free Cl, which has a pungent odor and bleaches moist litmus paper inserted in the tube.

PALLADIUM (Pd; bivalent and tetravalent; at.wt. 106.7)

One of the rare platinum metals. See Platinum.

PHOSPHORUS (P; pentavalent; at.wt. 31)

(1) **Ppt. with Ammonium Molybdate.** Dissolve the powdered mineral in HNO_3, previously fusing in soda bead if insol. Add a few drops of the sol. to a test tube containing ammonium molybdate and let stand a few minutes; a yellow ppt. forms.

(2) **Flame Color.** Pale bluish-green; moistening with H_2SO_4, is required with some minerals.

PLATINUM (Pt; bivalent and tetravalent, at.wt. 195.2)

(1) **Platinum** is recognized by its grayish-white color, infusibility, insolubility in any single acid, and reddish-yellow solution in aqua regia. It usually contains iron and traces of the other metals of the Platinum Group, of which the following are the most important:

(2) **Osmium** gives the very penetrating and disagreeable odor of OsO_4 when the fine powder is heated in c.t. with $NaNO_3$ or KNO_3.

(3) **Iridium** and **Iridosmine** are hard ($H = 6–7$), insoluble even in aqua regia. Fusion with $NaNO_3$ in c.t. oxidizes some Ir; break off the lower end of the tube and boil the mass in aqua regia. The solution becomes deep red to reddish-black.

(4) **Palladium** has a bluish tarnish, which is removed and a Pt-like color restored in r.f. and renewed by moderate heat in o.f.

POTASSIUM (K; univalent; at.wt. 39.1)

(1) **Flame Color.** Pale violet, obscured by Na; violet or purplish-red through blue glass, which eliminates the yellow of Na. For silicates mix with an equal volume of powdered gypsum and heat on a Pt wire the end of which has been moistened to make the powder adhere.

(2) **Alkaline Reaction.** Some K minerals, like those containing some other alkalis and the alkaline earths, give an alkaline reac. on moist turmeric paper after intense ignition.

For K in silicates, see Silicon (2).

SELENIUM (Se; bivalent and sexivalent; at.wt. 79.2)

(1) **Odor and Subl. on ch.** Radish-like odor. If abundant, brownish fumes form and a silvery SeO_2 coating, which may have a border of red from admixture of Se.

(2) **Flame Color.** The subl. obtained in (1) is volatile in r.f. and imparts a fine azure-blue color to the flame.

(3) **Subl. in o.t.** White crystalline SeO_2 subl. reddened by admixture of Se; volatile and give a beautiful blue color to flame if the end of the tube is held so that the fumes enter the reducing part of the Bunsen flame.

(4) **Subl. in c.t.** Fused black globules of Se, the smallest deep red to brown by transmitted light. Some white SeO_2 may form above the Se.

SILICON (Si; tetravalent; at.wt. 28.3)

(1) **Gelatinization.** Silicates that are completely soluble in acids give on continued boiling and evaporation a jelly of H_2SiO_3. HNO_3 is best, but HCl will serve in most cases.

(2) **Insol. Residue in Acids.** Insol. silica in powdery form remains after solution of the bases of some minerals. In suspension it makes the solution translucent and not so white and milky as the powder of an insol. mineral. Verify solution by evaporating a drop of the clear liquid on Pt foil or a watch glass (or a flake of mica if HCl or HNO_3 is used) and note considerable residue if solution has occurred.

Evaporate the solution obtained in (1) or (2) to dryness, moisten with conc. acid, and heat to boiling, then add 2 parts water and boil again. The bases go into sol. but the silica remains and is removed by filtering. For insol. silicates first fuse in beads on Pt wire with 3 parts of soda, dissolve in dil. HNO_3, evaporate to dryness, and proceed as before. It is convenient to use a double loop (Fig. 9*b*) and prepare 2 or 3

large beads, in order to provide a sufficient quantity for distinct reactions. This is especially important in the following tests.

Detection of Bases in Silicates. (*a*) To the filtrate from the preceding operations if not a nitric acid solution, add a little HNO_3, heat to boiling and add ammonia in slight excess. Al and Fe are precipitated as hydroxides ($Al(OH)_3$ and Fe $(OH)_3$). If the ppt. is light-colored there is little or no Fe; if it is reddish-brown there is considerable Fe and further test must be made for Al as follows: (*b*) Filter; place the ppt. in a test tube with a little water and a small fragment of stick potash (KOH) and boil. $Al(OH)_3$ goes into solution and is separated from insoluble $Fe(OH)_3$ by filtering. Make the filtrate acid with HCl, boil, and add ammonia in excess to precipitate $Al(OH)_3$ again.

(*c*) Heat filtrate from (*a*) to boiling and add a little ammonium oxalate to precipitate Ca. Let stand 10 minutes and filter. If filtrate is turbid, pass it repeatedly through the same filter till it comes through clear.

(*d*) Add to the filtrate from (*c*) a little more ammonium oxalate to make sure that all Ca has been removed. If no ppt. forms add sodium phosphate and strong ammonia to precipitate Mg. It may have to stand for some time after cooling before the precipitate forms.

(*e*) If alkalis are to be tested for, filter off the Mg ppt. of (*d*), evaporate the filtrate to dryness and heat to redness to drive off ammonia salts. Test the residue for K and Na flame colors with a Pt wire.

(3) **In s.ph. Bead.** An insol. skeleton of translucent silica remains when the powdered mineral is fused in s.ph. bead.

SILVER (Ag; univalent; at.wt. 107.9)

(1) **Metal on ch.** Fuse powdered mineral with 3 volumes of soda on ch.; a malleable metal globule is obtained which is bright both in the flame and after cooling. Test according to (2) below. Compounds with S, As, and Sb on roasting in o.f. on ch. yield Ag globule which is brittle with Sb.

(2) **Subl. on ch.** When Pb and Sb are present or have been added, the subl. of PbO and Sb_2O_3 on ch. is colored reddish to deep lilac by Ag.

(3) **AgCl Ppt.** Dissolve the mineral in conc. HNO_3 and dilute the sol.; add a few drops of HCl or a little common salt and a white ppt. of AgCl forms. Darkens on exposure to light and is sol. in ammonia. Collect ppt. on filter paper and test according to (1) above.

Sodium (Na; univalent; at.wt. 23)

(1) **Flame Color.** Deep yellow, invisible through dark blue glass. For non-vol. silicates mix powdered mineral with equal volume of powdered gypsum and heat on the point of a Pt wire which has been previously moistened so that powder will adhere.

(2) **Alkaline Reac.** Some Na minerals, like those containing most other alkalis and the alkaline earths, give alkaline reac. on moist turmeric paper after ignition.

For Na in silicates, see Silicon (2).

Strontium (Sr; bivalent; at.wt. 87.6)

(1) **Flame Color.** Crimson, from fragment in forceps or from powder on Pt wire moistened with HCl (faint yellow through green glass). Much like the Li flame; redder than the Ca flame and more persistent.

(2) **Alkaline Reac.** Like many minerals containing alkalis and other alkaline earths, some Sr minerals give alkaline reac. on moist turmeric paper after ignition. No Li minerals give this reaction.

(3) **Sulphate ppt.** A sol. of a Sr mineral gives a white ppt. of $SrSO_4$ on addition of a few drops of dil. H_2SO_4 (dif. from Li) if sol. is not very dilute or too much acid. Ppt. does not dissolve on addition of water and boiling, as does $CaSO_4$. This test is useful for silicates and phosphates, which do not yield tests (1) and (2).

SULPHUR (S; bivalent and sexivalent; at.wt. 32.1)

Sulphides:

(1) **Fumes in o.t. and on ch.** Finely powdered sulphides in o.t. give sharp pungent SO_2 fumes, which give acid reac. on moist litmus paper in upper end of tube. With Fe and Cu some white fumes of SO_3 appear and H_2SO_4 condenses in the tube. Similar results on ch. in o.f., but less delicate. Some sulphides give blue flame from burning S on ch.

(2) **Subl. in c.t.** Some sulphides yield in c.t. a subl. of S, which is a reddish liquid while hot and a yellow solid when cold.

(3) **Reac. with Soda.** Fuse powdered mineral b.b. on Pt foil, ch., or a flake of mica, with 3 volumes of soda, place the mass on clean Ag and moisten with water; a black stain of Ag_2S forms. The fused mass moistened with HCl yields H_2S, as in (5) below. This test is not reliable in the presence of Se and Te. Also the gas or ch. may give a slight reac. for S.

(4) **Sol. in HNO_3.** In hot conc. HNO_3 sulphides are oxidized with the formation of H_2SO_4 and red NO_2 fumes. Dilute part of the sol. and add $BaCl_2$; a white ppt. of $BaSO_4$ forms. Free S may also float on the solution, either yellow or black with particles of the mineral.

(5) **H_2S with HCl.** Some sulphides dissolve in HCl with the evolution of H_2S gas, which is recognized by its offensive odor.

Sulphates:

(1) **$BaSO_4$ ppt.** $BaCl_2$ added to a dil. HCl sol. of a sulphate gives a white ppt. of $BaSO_4$, which does not dissolve on addition of water and boiling, as does $CaSO_4$.

(2) **Reac. with Soda.** Fuse the powdered mineral with equal volume of powdered ch. and 2 volumes of soda on ch., Pt foil, or a flake of mica till effervescence ceases; then test on Ag or with HCl as in (3) for sulphides.

Tellurium (Te; bivalent; at.wt. 127.5)

(1) **Subl. on ch.** Heated in o.f. on ch. a white subl. of TeO_2 forms near assay, resembling Sb_2O_3. Subl. is vol. in r.f. and gives a pale greenish color to the flame.

(2) **Subl. in o.t.** Similar to results on ch.; subl. volatilizes very slowly and fuses into globules which are yellow while hot and white or colorless when cold.

(3) **Subl. in c.t.** Metallic globules of Te and white subl. of TeO_2, as in (2), form in c.t.

Tin (Sn; tetravalent; at.wt. 119)

(1) **Metal and Subl. on ch.** The powdered mineral fused on ch. in r.f. with equal volume of powdered ch. and 2 volumes of soda gives globules of white malleable Sn, which are bright in r.f. and become dull in the air. Long-continued ignition gives a white subl. of SnO_2 on ch. In somewhat conc. warm HNO_3 the metal does not dissolve but forms white H_2SnO_3. Distinguished from Pb and Bi by accompanying subl. on ch. and from Ag by subl. and dull surface of globule in air.

Titanium (Ti; trivalent and tetravalent; at.wt. 48.1)

(1) **S.ph. Bead Reac.** In o.f. yellow while hot, colorless cold; in r.f. yellow hot, delicate violet cold. Best reduced with a granule of Sn on ch. When other coloring elements are present use the next test (2).

(2) **Color of Sol.** After fusion with borax or soda and solution in HCl, the sol. assumes a delicate violet color on boiling with Sn.

(3) **Test with H_2O_2.** Fuse the mineral with soda, boil in a small amount of conc. H_2SO_4 and an equal volume of water

till clear. Dilute and add H_2O_2; the sol. becomes redh.-yellow to amber, according to the quantity of Ti.

TUNGSTEN (W; sexivalent; at.wt. 184)

(1) **S.ph. Bead Reac.** In o.f. colorless; in r.f. green hot, fine blue cold.

(2) **Residue in HCl.** When decomposed by HCl a yellow residue of WO_3 is obtained. Add Sn and continue boiling; a blue color is obtained, which finally changes to brown.

(3) **Fusion with Soda.** If insol. in HCl, fuse powder on Pt wire with 6 volumes of soda, pulverize and dissolve in water, filter, acidify with HCl, and boil with Sn. The blue sol. is obtained as in (2).

URANIUM (U; tetravalent and sexivalent; at.wt. 238.5)

(1) **S.ph. Bead Reac.** In o.f. yellow while hot, yelh.-green cold; in r.f. a fine green.

VANADIUM (V; pentavalent; at.wt. 51)

(1) **S.ph. Bead Reac.** In o.f. yellow to deep amber, fading a little on cooling; in r.f. dirty greenish while hot, fine green cold.

ZINC (Zn; bivalent; at.wt. 65.4)

(1) **Subl. on Ch.** Fuse powdered mineral on ch. with ½ its volume of soda and the same amount of powdered ch. ZnO subl. near the assay is pale yellow hot, white cold. Where ch. is previously moistened with $Co(NO_3)_2$ sol. the subl. is green.

(2) **Flame Color.** A large fragment heated near the tip of the blue flame colors it in streaks a vivid pale bluish-green.

(3) **Change of Color.** Many Zn minerals are straw-yellow or canary-yellow while hot and white when cold.

ZIRCONIUM (Zr; tetravalent; at.wt. 90.6)

(1) **Turmeric Paper Test.** Fuse the powdered mineral with soda in a loop of Pt wire and dissolve the bead in a small amount of HCl. Turmeric paper placed in the solution assumes an orange color, which is detected by comparing with a piece of turmeric paper in another tube containing only acid.

CRYSTALLIZATION

There are six systems of crystallization to which all crystals may be assigned. These are distinguished by degrees of symmetry, which is usually expressed in terms of lengths and inclinations of certain lines assumed in the crystal and called crystallographic axes.

(1) **Isometric System.** Three equal axes at right angles to each other. The simple forms and some of the combinations are shown in Figs. 11 to 30.

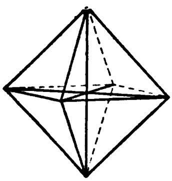

FIG. 11.

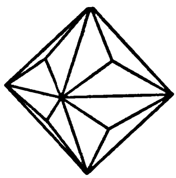

FIG. 12.

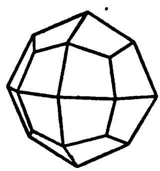

FIG. 13.

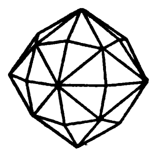

FIG. 14.

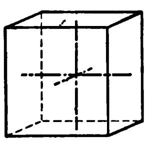

FIG. 15.

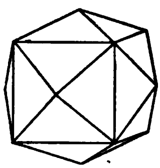

FIG. 16.

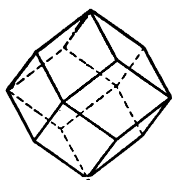

FIG. 17.

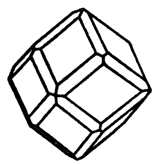

FIG. 18.

ISOMETRIC CRYSTALS: Fig. 11, Octahedron (111); 12, Trisoctahedron (221); 13, Trapezohedron (211); 14, Hexoctahedron (321); 15, Cube, or hexahedron (100); 16, Tetrahexahedron (210); 17, Dodecahedron (110); 18, Combination of dodecahedron and trapezohedron.

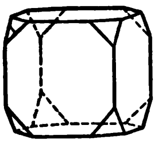

Fig. 19.

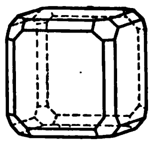

Fig. 20.

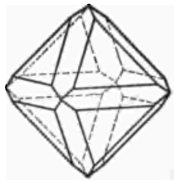

Fig. 21.

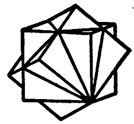

Fig. 22.

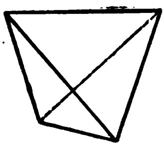

Fig. 23.

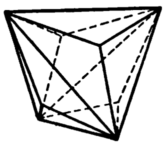

Fig. 24.

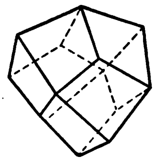

Fig. 25.

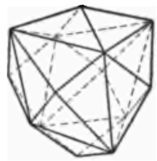

Fig. 26.

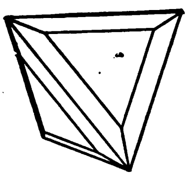

Fig. 27.

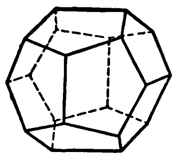

Fig. 28.

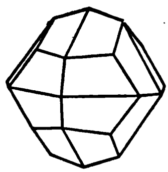

Fig. 29.

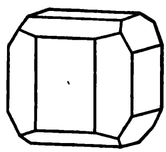

Fig. 30.

Isometric Crystals: Fig. 19, Combination of cube and octahedron; 20, Combinaton of cube, octahedron, and dodecahedron; 21, Combination of octahedron and dodecahedron; 22, Twinned cubes (a *penetration twin*); 23, Tetrahedron (111); 24, Tristetrahedron (211); 25, Deltohedron (221); 26, Hextetrahedron (321); 27, Combination of tetrahedron and tristetrahedron (tetrahedrite); 28, Pyritohedron (210); 29, Diploid (321); 30, Combination of cube and pyritohedron (pyrite).

(2) **Tetragonal System.** Three axes at right angles to each other; two are equal and the third is shorter or longer (Figs. 31 to 39).

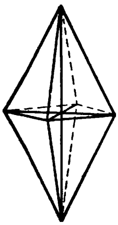

FIG. 31.

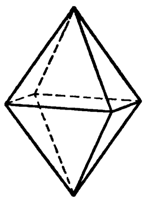

FIG. 32.

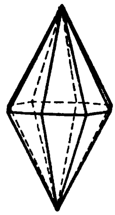

FIG. 33.

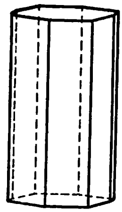

FIG. 34.

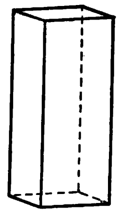

FIG. 35.

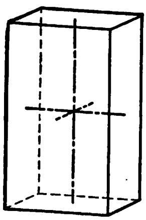

FIG. 36.

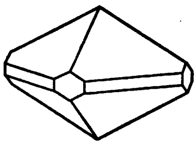

FIG. 37.

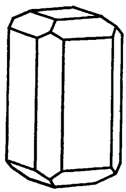

FIG. 38.

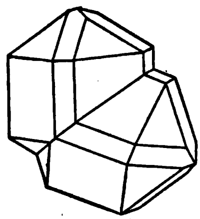

FIG. 39.

TETRAGONAL CRYSTALS: Fig. 31, Pyramid of the first order (111); 32, Pyramid of the second order (101); 33, Ditetragonal pyramid (212); 34, Ditetragonal prism (210); 35, Prism of the first order (110); 36, Prism of the second order (100); 37, Combination of first order prism and pyramid with second order prism (vesuvianite); 38, Combination of basal pinacoid with the same forms as Fig. 37 (vesuvianite); 39, Twin crystal of cassiterite (a *contact twin*).

(3) **Hexagonal System.** Three equal axes at 60° to each other in a horizontal plane; a fourth axis at right angles to these, vertical, is either shorter or longer (Figs. 40 to 51).

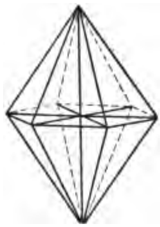

FIG. 40.

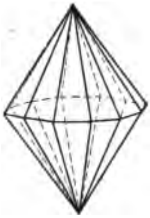

FIG. 41.

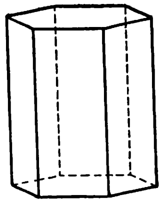

FIG. 42.

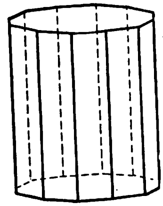

FIG. 43.

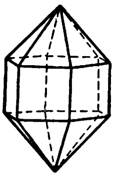

FIG. 44.

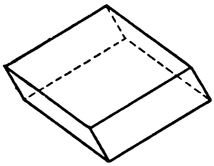

FIG. 45.

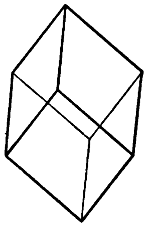

FIG. 46.

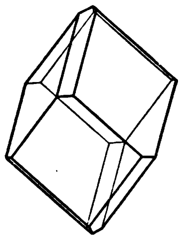

FIG. 47.

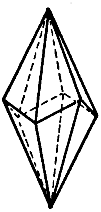

FIG. 48.

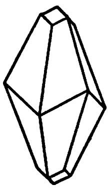

FIG. 49.

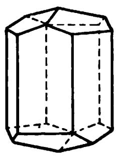

FIG. 50.

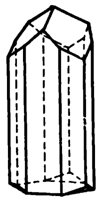

FIG. 51.

HEXAGONAL CRYSTALS: Fig. 40, Pyramid ($10\bar{1}1$); 41, Dihexagonal pyramid ($21\bar{3}1$); 42, Prism ($10\bar{1}0$); 43, Dihexagonal prism ($21\bar{3}0$); 44, Combination of prism and pyramid; 45, Rhombohedron ($10\bar{1}1$) (calcite), 46, Rhombohedron ($02\bar{2}1$) (calcite); 47, Combination of the two preceding rhombohedrons (calcite); 48, Scalenohedron ($21\bar{3}1$) (calcite); 49, Combination of scalenohedron and rhombohedron (calcite); 50, Combination of rhombohedron ($01\bar{1}2$) and prism (calcite); 51, Hemimorphic crystal (tourmaline).

(4) **Orthorhombic System.** Three unequal axes at right angles to each other (Figs. 52 to 59).

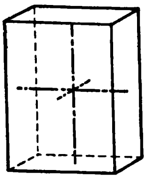

FIG. 52.

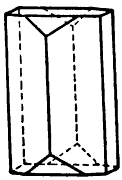

FIG. 53.

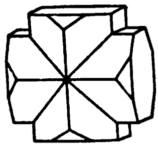

FIG. 54.

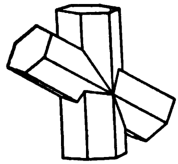

FIG. 55.

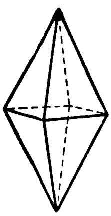

FIG. 56.

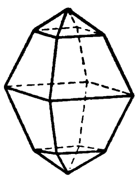

FIG. 57.

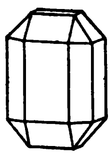

FIG. 58.

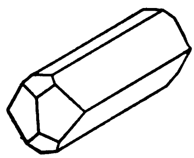

FIG. 59.

ORTHORHOMBIC CRYSTALS: **Fig.** 52, Combination of pinaciods (100), (010), and (001); 53, Combination of basal and brachy pinacoids with prism (110) and macro dome (101) (staurolite); 54, 55, Penetration twins (staurolite); 56, Pyramid (111) (sulphur); 57, Combination of pyramids (111) and (113) (sulphur); 58, Combination of prism, pyramid, domes, and pinacoids (chrysolite); 59, Combination of prism, domes, and basal pinacoid (celestite).

(5) **Monoclinic System.** Three unequal axes, two of which are inclined to each other and are at right angles to the third (Figs. 60 to 66).

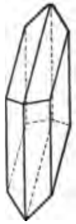
FIG. 60.

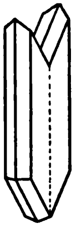
FIG. 61.

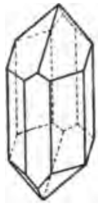
FIG. 62.


FIG. 63.

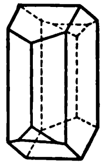
FIG. 64.

MONOCLINIC CRYSTALS: Fig. 60, Hemipyramid (111), prism (110), and clino pinacoid (010), in combination (gypsum); 61, Contact twin (gypsum); 62, Combination of hemipyramids (111) ($\bar{2}21$), prism (110), and pinacoids (100), (010) (pyroxene); 63, Combination of same forms with basal pinacoid (001) (pyroxene); 64, Combination of prism (110), pinacoids (010) (001), and hemi-ortho domes ($\bar{1}01$) ($\bar{2}01$) (orthoclase); 65, Penetration twin (orthoclase); 66, Prism (110), pinacoids (010) (001), and hemi-ortho dome ($\bar{2}01$) (orthoclase).

(6) **Triclinic System.** Three unequal axes, all inclined to each other (Figs. 67, 68).

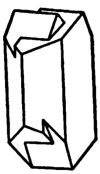
FIG. 65.

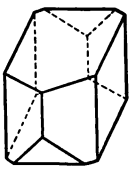
FIG. 66.

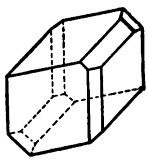
FIG. 67.

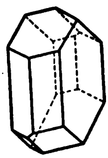
FIG. 68.

TRICLINIC CRYSTALS: Fig. 67, Combination of tetra-pyramids (111) (111), hemi-prisms, (110) ($1\bar{1}0$), macro pinacoid (100), and macro dome (201) (axinite); 68, Combination of brachy pinacoid (010), basal pinacoid (001), hemi-prisms (110) ($1\bar{1}0$), and tetra-pyramids ($11\bar{1}$) ($1\bar{1}\bar{1}$) (albite).

DESCRIPTIVE AND TECHNICAL TERMS

The following terms are commonly used in describing the characters of minerals.

Acicular. In slender needle-like crystals.

Adamantine. See Luster.

Amorphous. Non-crystalline structure, like opal or glass.

Anhydrous. Not yielding water in the closed tube. See Hydrous.

Arborescent. Branching like a tree; dendritic.

Bladed. Flattened and elongated, like a knife blade.

Botryoidal. With a surface consisting of small rounded prominences, somewhat like a bunch of grapes pressed closely together.

Brittle. Breaks to powder when cut or hammered.

Capillary. In hair-like or thread-like cyrstals.

Cleavage. The capacity for being split with smooth planes in certain fixed directions, generally parallel to common crystal faces. Cleavage is perfect when the mineral splits very easily. Directions are expressed by the names of the crystal forms; as cubic, parallel to the faces of a cube; octahedral, parallel to the faces of an octahedron, etc. Compare Parting.

Columnar. Parallel grouping of prisms or columns.

Compact. Being a firm aggregate of exceedingly minute particles, like clay.

Conchoidal. See Fracture.

Crystalline. Having regular structure, which, in the absence of crystals, is often shown by cleavage.

Dendritic. Branching like a tree or like fern leaves; arborescent.

Drusy. Covered with minute crystals, giving a rough surface with many glittering faces.

Dull. Without luster or shine of any kind.

Earthy. Clay-like, dull, and composed of minute particles.

Elastic. Springing back when bent, as in plates of mica.

Fibrous. Composed of minute threads, usually with a satiny luster, like asbestos.

Flexible. May be bent without breaking.

Foliated. Separating readily into thin plates; lamellar.

Fracture. The manner of breaking that does not produce smooth planes of cleavage or parting; designated as *conchoidal* when rounded or curved surfaces are produced; *uneven* when rough and irregular; *hackly,* sharp, jagged surfaces, like broken metals; *splintery* when elongated splinters or needles are produced.

Fusibility. Capacity for being fused or melted in the blowpipe flame.

Globular. Having a surface composed of rounded prominences, somewhat larger and more prominent than botryoidal.

Glowing. Emission of a bright light when intensely heated; a property of infusible substances, particularly oxides of Ca, Mg, Zr, and Th.

Granular. Consisting of crystalline grains or particles of about uniform size.

Greasy. See Luster.

Hackly. See Fracture.

Hardness. Resistance to being scratched, commonly indicated by numbers according to the following 10 minerals, called the *Scale of Hardness:* 1. Talc; 2. Gypsum; 3. Calcite; 4. Fluorite; 5. Apatite; 6. Orthoclase; 7. Quartz; 8. Topaz; 9. Corundum; 10. Diamond. With a little practice the degree of hardness can be determined very closely by the use of the

finger nail (a little above 2), a knife blade (a little above 5), and a piece of quartz (7), by noting the ease or difficulty with which a mineral is scratched by one of these.

Hemimorphic. Having crystals with the opposite ends differently terminated.

Hydrous. Yielding water when heated in the closed tube; from water of crystallization, hydroxyl, or acid hydrogen.

Iridescent. Having colors like a soap bubble; often due to a thin coating or a slight surface alteration.

Isomorphic. Elements or compounds capable of replacing each other in all proportions or of crystallizing together to form homogeneous mixed crystals are called isomorphic. Thus calcite, $CaCO_3$, may contain varying amounts of $MgCO_3$, $FeCO_3$, and $MnCO_3$; Fe, Zn, Pb, and Ag may replace part of the Cu in tetrahedrite (gray copper ore); etc.

Lamellar. See Foliated.

Luster. The appearance of a mineral due to its manner of reflecting and refracting light; designated as *metallic,* the luster of a metal; *submetallic, metalloidal,* somewhat like a metal. Metallic and submetallic minerals are opaque and give very dark-colored powder or streak. Non-metallic lusters include *vitreous,* like glass; *adamantine,* brilliant, like diamond; *resinous,* the appearance of resin; *greasy* or *oily,* as if slightly oiled; *pearly,* like mother of pearl; *silky,* like satin, due to parallel fibers.

Magnetic. Capable of attracting the magnetic needle or of being attracted by a steel magnet. Some pieces of magnetic minerals will act as magnets themselves, as magnetite, pyrrhotite, and platinum.

Malleable. Capable of being hammered into flat pieces.

Mammillary. Having a smooth surface with rounded hummocky protuberances.

Massive. Without crystal form or faces.

Metallic, Metallodial. See Luster.

Micaceous. Cleaving easily into very thin sheets, like mica.

Nodular. In rounded lumps or nodules.

Oily. See Luster.

Oolitic. Composed of minute rounded grains, like fish roe.

Opalescent. Having a milky or pearly internal reflection.

Parting. A splitting much like cleavage but occurring only at certain irregular intervals, while cleavage can be produced as readily at one point as another.

Pearly. See Luster.

Phosphorescent. Giving off light when gently heated—below red heat.

Pinacoidal. Parallel to the faces of a pinacoid, as cleavage.

Pisolitic. Consisting of rounded particles about the size of peas.

Prismatic. Parallel to the faces of a prism, as cleavage; also said of crystals that are elongated in one direction.

Pseudomorphic. Having the crystal form of another mineral, owing to alteration, replacement, etc.

Pyramidal. Parallel to pyramid faces, as cleavage; or having faces that meet in a point.

Pyroelectric. Becoming electric so as to attract minute particles of tissue paper and other light bodies when moderately heated. A small fragment of the mineral is generally best.

Radiated. Having fibers, columns, or plates diverging from a central point.

Reniform. Having a smooth, rounded, kidney-like surface.

Resinous. See Luster.

Reticulated. Slender crystals crossing like the meshes of a net.

Sectile. Slices or shavings may be cut off with a knife.

Silky. See Luster.

Specific Gravity. Weight compared with an equal volume of water; thus a mineral of G. 2.5 is two and a half times as

heavy as water. When the weight of a mineral in air is a, and its weight in water is w, $G=\frac{a}{a-w}$. A chemical balance may be used or one specially designed for this purpose. Whether a mineral is high or low specific gravity or intermediate can generally be judged by the hand without weighing.

Splendent. Having a brilliant luster.

Splintery. See Fracture.

Stalactitic. In icicle-like pendant forms.

Streak. The color of the fine powder of a mineral or of the mark it will make on a harder white substance. The streak plate of dull white porcelain is convenient for testing minerals below 5.5 in hardness. The same result is obtained by grinding a particle of the mineral in a mortar or between hammer and anvil, if these are entirely clean and free from rust.

Striated. Marked with fine parallel lines or grooves.

Submetallic. See Luster.

Tabular. In broad flattened crystals.

Tarnish. A color different from the fresh mineral, caused by alteration of the surface.

Uneven. See Fracture.

Vitreous. See Luster.

CHEMICAL ELEMENTS

Symbol.	Element.	Atomic Weight.	Symbol.	Element.	Atomic Weight.
A	Argon	39.88	Ho	Holmium	163.45
Ag	Silver (Argentum)	107.88	I	Iodine	126.92
Al	Aluminum	27.1	In	Indium	114.8
As	Arsenic	74.96	Ir	Iridium	193.1
Au	Gold (Aurum)	197.2	K	Potassium (Kalium)	39.10
B	Boron	11.0	Kr	Krypton	82.9
Ba	Barium	137.37	La	Lanthanum	139.0
Be	Beryllium (see Glucinum).		Li	Lithium	6.94
			Lu	Lutecium	174.0
Bi	Bismuth	208.0	Mg	Magnesium	24.32
Br	Bromine	79.92	Mn	Manganese	54.93
C	Carbon	12.00	Mo	Molybdenum	96.0
Ca	Calcium	40.07	N	Nitrogen	14.01
Cb	Columbium	93.5	Na	Sodium (Natrium)	23.00
Cd	Cadmium	112.40	Nb	Niobium (see Columbium).	
Ce	Cerium	140.25			
Cl	Chlorine	35.46	Nd	Neodymium	144.3
Co	Cobalt	58.97	Ne	Neon	20.2
Cr	Chromium	52.0	Ni	Nickel	58.68
Cs	Caesium	132.81	Nt	Niton	222.4
Cu	Copper (Cuprum)	63.57	O	Oxygen	16.000
Dy	Dysprosium	162.5	Os	Osmium	190.9
Er	Erbium	167.7	P	Phosphorus	31.04
Eu	Europium	152.0	Pb	Lead (Plumbum)	207.10
F	Fluorine	19.0	Pd	Palladium	106.7
Fe	Iron (Ferrum)	55.84	Pr	Praseodymium	140.6
Ga	Gallium	69.9	Pt	Platinum	195.2
Gd	Gadolinium	157.3	Ra	Radium	226.4
Ge	Germanium	72.5	Rb	Rubidium	85.45
Gl	Glucinum	9.1	Rh	Rhodium	102.9
H	Hydrogen	1.008	Ru	Ruthenium	101.7
He	Helium	3.99	S	Sulphur	32.07
Hg	Mercury (Hydrargyrum)	200.6	Sb	Antimony (Stibium)	120.2
			Sc	Scandium	44.1

CHEMICAL ELEMENTS—*Continued*

Symbol.	Element.	Atomic Weight.	Symbol.	Element.	Atomic Weight.
Se	Selenium	79.2	Tu	Thulium	168.5
Si	Silicon	28.3	U	Uranium	238.5
Sm	Samarium	150.4	V	Vanadium	51.0
Sn	Tin (Stannum)	119.0	W	Tungsten (Wolframium)	184.0
Sr	Strontium	87.63	X	Xenon	130.2
Ta	Tantalum	181.5	Y	Yttrium	89.0
Tb	Terbium	159.2	Yb	Ytterbium	172.0
Te	Tellurium	127.5	Zn	Zinc	65.37
Th	Thorium	232.4	Zr	Zirconium	90.6
Ti	Titanium	48.1			
Tl	Thallium	204.0			

ABBREVIATIONS

(For symbols of chemical elements, see page 58)

abund.	abundant
acic.	acicular
adamant.	adamantine
am.	ammonia
am.mol.	ammonium molybdate
amorph.	amorphous
amt.	amount
anhydr.	anhydrous
Ap.I, II	Appendix I or II to Dana's "System of Mineralogy"
at.wt.	atomic weight
b.b.	before the blowpipe
bd.	bead
blk., blkh.	black, blackish
bot.	botryoidal
bp.	blowpipe
brn., brnh.	brown, brownish
C., cleav.	cleavage
capil.	capillary
ch.	charcoal
col.	color, colored
cols.	colorless
conc.	concentrated
conch.	conchoidal
cp.	compare
c.t.	closed tube
dif.	difficultly
dil.	dilute
disting.	distinguished
dk.	dark
dodec.	dodecahedral
efferv.	effervesces, effervescence
F., fract.	fracture
fibr.	fibrous
flex.	flexible
fol.	foliated
fus.	fuses, fusion, fusibility

G., sp.g.	specific gravity
gel.	gelatinizes, gelatinous
gran.	granular
grn., grnh.	green, greenish
gry., gryh.	gray, grayish
H.	hardness
hemimor.	hemimorphic
hex.	hexagonal
ign.	ignition
incrust.	incrustation
intumes.	intumesces, intumescence
iso.	isometric, isomorphic
lamel.	lamellar
lt.	light
mammil.	mammillary
mm.	millimeter (1-25 inch)
mag.	magnetic
mass.	masses, massive
mon.	monoclinic
non-mag.	non-magnetic
non-vol	nonvolatile
oct.	octahedral
o.f.	oxidizing flame
opaq.	opaque
orth.	orthorhombic
o.t.	open tube
P., part.	parting
per.	perfect
phys.	physical
pinac.	pinacoidal
ppt.	precipitate
prism.	prismatic
pseudm.	pseudomorphic
pyr.	pyritohedral
pyram.	pyramidal
rad.	radial, radiating
rdh.	reddish
reac.	reacts, reaction
res.	residue, resinous
rhom.	rhombohedral
S.	Dana's "System of Mineralogy"
sil.	silica (SiO_2)
sol.	soluble, solution
somet.	sometimes
sp.g., G.	specific gravity

s.ph.	sodium metaphosphate
splint.	splintery
st.	streak
subl.	sublimate
submet.	submetallic
T.	Dana's "Textbook of Mineralogy
tab.	tabular
tar.	tarnishes, tarnish
temp.	temperature
tetr.	tetragonal
tetrh.	tetrahedral
transp.	transparent, transparency
transl.	translucent, translucence
tri.	triclinic
us.	usually
vesic.	vesicular
vitr.	vitreous
vol.	volatilizes, volatile
w.	with
wh., whh.	white, whitish
xl., xls.	crystal, crystals
xln.	crystalline, crystallization
yel., yelh.	yellow, yellowish

PRECAUTIONS CONCERNING THE USE OF TABLES.

(1) All tests should be made upon fresh material, preferably crystalline. If an impurity is known to be present its effect must be carefully allowed for and not attributed to the mineral.

(2) All tests must be made with care and only clear, decided reactions taken into account. Weak, uncertain results may be due either to a small amount of some impurity or to careless or hasty manipulation.

(3) Physical properties, such as luster, color, and hardness, must be determined on clean, fresh surfaces.

(4) The powdered mineral to be used in the various tests should be prepared by crushing and grinding (not pounding) small grains of pure material in an agate mortar (if not harder than 6.5) or under a hammer on any clean surface of iron or steel. If the mineral is rare and but little can be used for determination a steel "diamond" mortar may be used, or fragments may be wrapped in 2 or 3 folds of paper and pounded with a hammer.

(5) The tables are constructed on the plan of eliminating one group of minerals after another until the proper species is found; hence the order as given must be followed strictly, both in the general table and in the sections to which it refers.

(6) Each test should be recorded as soon as made whether results are negative or positive. This may be done in systematic order in a notebook or on blanks provided for that purpose.

DETERMINATIVE TABLES

GENERAL TABLE

	Section	Page
I. Metallic or Submetallic Luster.		
The streak is black or dark colored.		
A. Fusible, at least on thin edges (fus. 1–5), or volatile.		
1. Arsenic minerals.—A white sublimate forms on charcoal far from the assay; usually also gives a garlic odor..	1	66
2. Antimony minerals.—A dense white sublimate forms on the charcoal near the assay..................	2	68
3. Sulphides not previously included.—Fumes of sulphur dioxide are given in the open tube, if not on charcoal, and acid reaction on moist blue litmus paper placed in the upper end of the tube....................	3	70
4. Not previously included..........................	4	72
B. Infusible or nearly so (fus. above 5).		
1. Iron minerals.—Become strongly magnetic after heating in the reducing flame and cooling............	5	76
2. Manganese minerals.—A minute quantity gives a manganese reaction in soda or borax bead; soluble in hydrochloric acid with evolution of chlorine gas....	6	78
3. Not previously included..........................	7	78
II. Without Metallic Luster.		
The streak is light-colored or white.		
A. Easily volatile or combustible.........................	8	80
B. Fusible, at least on thin edges (fus. 1–5), or slowly or partially volatile.		
Part I. Give a globule of metal when fused with an equal volume of powdered charcoal and 3 times its volume of soda on charcoal.		
1. Lead minerals.—Globules of lead and a yellow coating. With "bismuth flux" a chrome-yellow coat, darker while hot.................................	9	82
2. Copper minerals.—Globule of copper; copper reactions in acids..................................	10	84
3. Silver minerals.—Silver globule, brittle when containing antimony..................................	11	84
4. Bismuth minerals.—Brittle bismuth globules and yellow sublimate. A red sublimate with "bismuth flux"..	12	86

Part II. Become magnetic after heating in the reducing flame and cooling. Iron, cobalt, and nickel minerals.

1. Soluble in hydrochloric acid without residue* or gelatinous silica upon evaporation.................... 13 86
2. Soluble in hydrochloric acid with the formation of gelatinous silica or decomposed with separation of silica.. 14 88
3. Insoluble in hydrochloric acid or nearly so.......... 15 90

Part III. Not included in the foregoing parts I and II.

1. Alkaline reaction on moist turmeric paper after intense ignition.
   a. Easily and completely soluble in water............ 16 92
   b. Insoluble in water or slowly or partially soluble.... 17 94
2. Soluble in hydrochloric acid without residue* or gelatinous silica upon evaporation.................... 18 96
3. Soluble in hydrochloric acid with the formation of gelatinous silica upon evaporation.
   a. Give water in the closed tube.................... 19 98
   b. Little or no water given off in the closed tube...... 20 100
4. Decomposed by hydrochloric acid with separation of silica but without complete solution or the formation of jelly.
   a. Give water in the closed tube.................... 21 102
   b. Little or no water in the closed tube.............. 22 104
5. Insoluble in hydrochloric acid or nearly so.......... 23 106

C. Infusible or nearly so (fus. above 5).

1. Alkaline reaction on moist turmeric paper after intense ignition.. 24 116
2. Soluble in hydrochloric acid without residue* or the formation of gelatinous silica upon evaporation.... 25 118
3. Soluble in hydrochloric acid with the formation of gelatinous silica upon evaporation................ 26 120
4. Decomposed by hydrochloric acid with separation of silica but without complete solution or the formation of jelly.. 27 122
5. Insoluble in hydrochloric acid or nearly so.
   a. Can be scratched with a knife; not so hard as glass.. 28 124
   b. Cannot be scratched with a knife; as hard as glass or harder.. 29 126

* This is on the assumption that only the pure mineral is being tested. It often happens, however, that insoluble impurities are present, either as inclusions in crystals or in admixture with granular and earthy minerals. Such impurities must be carefully looked for, and due allowance must be made for them when their presence is known.

		Name.	Composition.
Mag. globule on ch.	As and S reac. in o.t. As in c.t.	**ARSENOPYRITE** (Mispickel) T303 S97	FeAsS (Co iso. w. Fe)
	As, but little or no S	Löllingite (Leucopyrite) T303 S96	$FeAs_2$ to Fe_3As_4
Cu flame on ch. after roasting and moistening with HCl. SO_2 fumes in o.t.	Disting. by phys. properties. (Cp. tetrahedrite)	**Enargite** T315 S147	Cu_3AsS_4
		TENNANTITE T313 S137	$Cu_8As_2S_7$ (Ag, Zn, Fe, Sb, is
	Ag w. soda on ch. (Cp. polybasite)	**Pearceite** T 315 Ap.I. 50	$(Ag,Cu)_9AsS_6$
Cu flame on ch. as above; no SO_2 fumes in o.t.	Disting. by phys. properties. All tar. to bnh. color. Whitneyite is rdh. on rubbed surface.	Domeykite T286 S44	Cu_3As
		Algodonite T286 S45	Cu_6As
		Whitneyite T286 S45	Cu_9As
Co in borax bd. after roasting. Rose col. sol. in conc. HNO_3. (Cp. Ni minerals, below.)	As subl. in c.t.	**Smaltite** T301 S87	$CoAs_2$ (Fe, Ni iso. w. Co)
	As and S reac. in o.t.	**Cobaltite** T301 S89	CoAsS (Fe iso. w. Co)
		Glaucodote T304 S101	(Co,Fe)AsS
Ni in borax bd. after roasting. (May be masked by Co.) Apple-grn. sol. in HNO_3	As subl. in c.t.	**Chloanthite** T301 S88	$NiAs_2$ (Fe, Co iso. w. Ni)
	As in c.t. on intense ign.	**Niccolite** (Copper Nickel) T295 S71	NiAs (Fe, Co iso. w. Ni)
	As and S reac. in o.t.	**Gersdorffite** T302 S90	NiAsS (Fe, Co iso. w. Ni)
Vol. on ch. without fusion	As subl. in c.t.	**Arsenic** T274 S11	As (Sb iso. w. As)
Pt sponge in o.t. (Heat gently at first.)	Pt insol in any single acid	Sperrylite T302 S92	$PtAs_2$

TION 1.

n.	Color.	Streak.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
	Ag-wh. to Fe-gry.	Blk.	5.5–6	5.9–6.2	2	Orth.; us. xls.	C. prism. F. uneven
	Ag-wh. to steel-gry.	Blk.	5–5–5	7.0–7.4	2	Orth.; us. mass.	C· basal F. uneven
	Gryh-blk.	Gry-blk.	3	4.43–4.45	1	Orth.; us. xls.	C. prism., per. F. uneven
, iso.)	Dk. Pb-gry. to Fe-blk.	Blk. to dk. cherry-red	3–4	4.37–4.49	1.5	Iso. tetrh.; xls. & mass.	F. uneven
	Blk.	Blk.	3	6.12–6.17	1	Mon.; tabular & mass.	F. conch.
	Sn-wh. to steel-gry.	Gry.	3–3.5	7.2–7.75	2	Massive	F. uneven
	Steel-gry.	Gry.	4	7.62	2	Massive	F. uneven
	Pale rdh. to gryh-wh.	Ag-wh.	3.5	8.4–8.6	2	Massive	Malleable F. hackly
o)	Sn-wh.	Blk.	5.5–6	6.4–6.6	2.5	Iso. pyr.; us. mass.	C. oct. F. uneven
	Ag-wh to gry. w. rdh. tone	Blk.	5.5	6–6.3	2–3	Iso. pyr.; us. xls.	C. cubic, per. F. uneven
	Gryh-wh.	Blk.	5	5.90–6.01	2–3	Orth.	C. basal F. uneven
l)	Sn-wh.	Gryh-blk.	5.5–6	6.4–6.6	2	Iso. pyr.; us. mass.	C. oct. F. uneven
l)	Pale Cu-red.	Pale brnh-blk.	5–5.5	7.33–7.67	2	Hex.; us. mass.	F. uneven
l)	Sn-wh.	Blk.	5.5	5.6–6.2	2	Iso. pyr.; us. mass.	C. cubic F. uneven
	Sn-wh.; tar. dk. gry.	Gry.	3.5	5.63–5.73	Vol.	Hex. rhom.; us. gran.	C. basal, per.
	Sn-wh.	Blk.	6–7	10.60	2	Iso. pyr.	F. conch.

		Name.	Composition.
Easily and completely vol. on ch.; no Pb reac.	Wh. slowly vol. subl. in o.t.	**Antimony** T275 S12	Sb
	SO_2 and wh. non-vol. subl. in o.t.	**STIBNITE** (Antimony Glance) T283 S36	Sb_2S_3
Pb reac. after roasting and fus. on ch. w. "bismuth flux"	Ag reac. with HNO_3 sol.	Freieslebenite T309 S124	$(Pb,Ag_2)_5Sb_4S_{11}$
	Cu reac. with HNO_3 sol.; steel-gry.	**Bournonite** T310 S126	$(Pb,Cu_2)_3Sb_2S_6$
	No Ag or Cu. Disting. by xln. and phys. characters	**Jamesonite** (Feather Ore) T308 S122	$Pb_2Sb_2S_5$
		Zinkenite T307 S112	$PbSb_2S_4$
		Boulangerite T309 S129	$Pb_5Sb_4S_{11}$
Ag reac. in HNO_3 sol. w. HCl; no Pb. Ag globule after roasting and fus. w. soda on ch. Subl. red to lilac when only Ag, Sb, and S are present	Cu reac. in HNO_3 sol.; gry.	**Freibergite** (Ag Tetrahedrite) T313 S137	$(Cu,Ag)_8Sb_2S_7$ (Fe, Zn iso. w. Cu_2)
	Deep red to blk.; st. Indian-red	**Pyrargyrite** (Ruby Silver: Dark Red Silver Ore) T311 S131	Ag_3SbS_3
	Blk., stout 6-sided (orth.) prisms	**Stephanite** (Brittle Silver Ore) T314 S143	Ag_5SbS_4
	Blk., 6-sided (mon.) plates; triangular markings on basal plane	**Polybasite** T314 S146	$(Ag,Cu)_9SbS_6$ (As iso. w. Sb)
	Sb and Ag reac. No S	Dyscrasite T286 S42	Ag_3Sb
Cu reac. in HNO_3 sol. No Pb or Ag globule w. soda on ch.	May contain Pb, Ag, Zn, Fe, and As	**TETRAHEDRITE** (Gray Copper) T312 S137	$Cu_8Sb_2S_7$ (Fe, Zn, Pb, Ag iso. w. Cu; As iso. w. Sb)

CTION 2.

ion.	Color.	Streak.	Hard- ness.	Specific Gravity.	Fusi- bility.	Crystalliza- tion.	Cleavage and Fracture.
	Sn-wh.	Sn-wh.	3–3.5	6.64–6.72	1	Hex. rhom.; us. mass.	C. basal, per.
	Pb-gry.	Pb-gry.	2	4.52–4.62	1	Orth.; us. xls.	C. pinac. per. F. uneven
n	Steel-gry.	Steel-gry.	2–2.5	6.2–6.4	1	Mon.	F. uneven
	Steel-gry.	Fe-gry.	2.5–3	5.7–5.9	1	Orth.; us. xls.	F. uneven
	Blkh-gry.	Gryh-blk.	2–3	5.5–6.0	1	Orth.; us. capil.	C. basal, per. F. uneven
	Steel-gry.	Steel-gry.	3–3.5	5.30–5.35	1	Orth.	F. uneven
	Bluish Pb-gry.	Blk.	2.5–3	5.75–6.0	1	Orth.	F. smooth
Cu)	Steel-gry.	Blk., often rdh.	3–4	4.85–5.0	1.5	Iso. tetrh.	F. uneven
	Deep red to blk.	Purplish red	2.5	5.77–5.86	1	Hex. rhom.; hemimor.	C. rhom. F. conch.
	Fe-blk.	Fe-blk.	2–2.5	6.2–6.3	1	Orth.	F. uneven
	Fe-blk.	Blk.	2–3	6–6.2	1	Mon.	F. uneven
	Ag-wh.	Ag-wh.	3.5–4	9.44–9.85	1.5	Orth.; us. massive	C. basal
. w. b)	Gry. to Fe-blk.	Gry. to Fe-blk.	3–4	4.4–5.1	1.5	Iso. tetrh., Fig. 27	F. uneven

			Name.	Composition.
Ag globule in o.f. on ch.	Contains only Ag and S. Sectile		**Argentite** (Silver Glance) T288 S46	Ag_2S
Pb globule and yel. subl. on ch.	No Bi		**GALENA** (Galenite) T287 S48	PbS
Cu flame on ch. after roasting and moistening w. HCl	Mag. in o.f. (Stannite only after long ign.)	Brass-yel.	**CHALCOPYRITE** (Copper Pyrites) T297 S80	$CuFeS_2$
		Brnh-bronze, purple tar.	**BORNITE** (Peacock Ore) T297 S77	Cu_3FeS_3
		Steel-gry.; wh. subl. in o.f.	**Stannite** (Tin Pyrites) T315 S83	Cu_2FeSnS_4 (Sn iso. w. Fe)
	Not mag. in o.f.	Cu in r.f. after roasting. Covellite much S in c.t., Chalcocite none	**CHALCOCITE** (Copper Glance) T290 S55	Cu_2S
			Covellite T294 S68	CuS
		Ag reac. in HNO_3 sol.	**Stromeyerite** T 290 S56	$(Ag,Cu)_2S$
Mag. in o.f.; no Cu. Contains Fe, Co or Ni	Pale brass-yel. Completely sol. in cold conc. HNO_3		**PYRITE** (Iron Pyrites; Fool's Gold) T300 S84	FeS_2
	Pale brass-yel. to wh. S separates from cold conc. HNO_3 sol.		**MARCASITE** (White Iron Pyrites) T302 S94	FeS_2
	Brnh-bronze; us. mag.; st. blk.		**PYRRHOTITE** (Magnetic Pyrites; Mundic) T296 S73	FeS (Ni iso. w. Fe)
	Zn reac. w. soda on ch. Submetallic luster		**SPHALERITE** (Zinc Blende; Black Jack) T291 S59	ZnS (Fe, Mn iso. w. Zn)
	Ni in borax bd. after roasting. HNO_3 sol. grn. Millerite capillary xls. or velvety crusts; Pentlandite gives Fe ppt. w. am. from HNO_3 sol.		**Millerite** (Hair Pyrites) T295 S70	NiS
			Pentlandite T293 S65	(Fe,Ni)S
	Co in borax bd. after roasting. HNO_3 sol. rose col.		**Linnaeite** T297 S78	$(Co,Ni)_3S_4$ (Fe, Cu iso. w. Co)
	Ag globule w. borax on ch. Flakes flexible		Sternbergite T290 S57	$AgFe_2S_3$

Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Blkh-gry.	Blkh-gry.	2–2.5	7.2–7.36	1.5	Iso.	F. conch.
Pb-gry.	Pb-gry.	2.5	7.4–7.6	2	Iso.; us. xls. or gran.	C. cubic, per.
Brass-yel.	Grnh-blk.	3.5–4	4.1–4.3	2	Tet. sphenoidal; us. mass.	F. uneven
Brnh-red bronze Purplish tar.	Pale gryh-blk.	3	4.9–5.4	2.5	Iso.; us. mass.	F. uneven
Steel-gry. to Fe-blk.	Blkh.	4	4.3–4.5	1.5	Iso. tetrh.; us. mass.	F. uneven
Dk. Pb-gry. Blkh. tar.	Dk. Pb-gry.	2.5–3	5–5.8	2–2.5	Orth.; us. mass.	F. uneven
Indigo-blue	Pb-gry. to blk.	1.5–2	4.59–4.64	2.5	Hex.; us. mass.	C. basal, per.
Dk. steel-gry.	Dk. steel-gry.	2.5–3	6.15–6.3	1.5	Orth.; us. mass.	F. uneven
Pale brass-yel.	Grnh-blk. to brnh-blk.	6–6.5	4.95–5.10	2.5–3	Iso. pyr. Figs. 28, 30	F. uneven
Pale yel. to almost wh.	Gryh. or brnh-blk.	6–6.5	4.85–4.90	2.5–3	Orth.; tabular; pryam.	F. uneven
Yelh-brh. bronze	Blk.	3.5–4.5	4.58–4.65	2.5–3	Hex.; us. mass.	P. basal F. uneven
Dk. brn. to blk.	Lt. to dk. brn.	3.5–4	3.9–4.1	5	Iso. tetr.; us. mass.	C. dodec., per.
Brass-yel.	Grnh-blk.	3–3.5	5.3–5.65	1.5–2	Hex.rhom.; us. capil.	C. rhom. F. uneven
Lt. bronze yel.	Lt. bronze to brn.	3.5–4	4.6	1.5–2	Iso.	C. oct. F. uneven
Pale steel-gry.; tar. Cu-red	Gryh-blk.	5.5	4.8–5	2	Iso.	F. uneven
Brnh-bronze	Blk.	1–1.5	4.1–4.22	1.5	Orth.	C. basal, per.

		Name.	Composition.
Bi reac. w. "bismuth flux"	Contains only Bi and S	**Bismuthinite** (Bismuth Glance) T284 S38	Bi_2S_3
Mn in borax bd. after roasting	H_2S in HCl	**Alabandite** T292 S64	MnS
Rdh-violet sol. when gently heated in conc. H_2SO_4.—Tellurium minerals.		See Section 4.	

SECT

Native metal, malleable		Cu reac. w. HNO_3 sol.	**COPPER** T278 S20	Cu
		Ag reac. w. HNO_3 sol. (Cp. amalgam below)	**SILVER** T278 S19	Ag (Somet. w. Au, Cu,
		Insol. in HNO_3; us. some Ag	**GOLD** T275 S14	Au (Us. w. some Ag)
		Insol. in HNO_3; much Ag	**ELECTRUM** T276 S15	(Au,Ag)
		Grnh-yel. subl. w. "bismuth flux" on ch.	Lead T279 S24	Pb
Native metal, brittle or liquid		Bright red subl. on ch. w. "bismuth flux"	**Bismuth** T275 S13	Bi
		Hg subl. in c.t.; amalgam leaves Ag res.	Mercury (Quicksilver) T279 S22	Hg
			Amalgam T279 S23	(Ag,Hg)
Mag. or becomes so in r.f. Contains Fe (Cp. the dark micas, sec. 23, which are sometimes submetallic)	Little or no H_2O in c.t.	Strongly mag. before heating	**MAGNETITE** (Magnetic Iron Ore; Lodestone) T339 S224	$FeFe_2O_4$ (Somet. Mg, Mn, T
		Nonmag. or but slightly so before heating	**HEMATITE** (Specular Iron) T334 S213	Fe_2O_3
	(Continued next page)		Martite T336 S216	Fe_2O_3

	Color.	Streak.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
	Lt. Pb-gry.	Lt. Pb-gry.	2	6.4–6.5	1	Orth.; us.mass.	C. pinac., per.
	Fe-blk. Brn. tar.	Olive-grn.	3.5–4	3.95–4.04	3	Iso. tetr.; us. mass.	C. cubic, per.

ION 4.

	Cu-red, Tar. blk.	Cu-red, shiny	2.5–3	8.8–8.9	3	Iso.; us. mass.	F. hackly
Hg)	Ag-wh.; tar. gry. to blk.	Ag-wh., shiny	2.5–3	10.1–11.1	2	Iso.; us. acic. plates or mass.	F. hackly
	Au-yel	Au-yel., shiny	2.5–3	15.6–19.33	2.5–3	Iso.; us. mass.	F. hackly
	Yelh-wh.	Yelh-wh., shiny	2.5–3	12.5–15.5	2–2.5	Iso.	F. hackly
	Pb-gry.	Pb-gry., shiny	1.5	11.37	1	Iso.; us.plates and globular	F. hackly
	Ag-wh., rdh. hue	Ag-wh., shiny	2–2.5	9.7–9.83	1	Hex. rhom.; us. gran.	C. basal, per.
	Sn-wh.	....	......	13.596	Vol.	Liquid	
	Ag-wh.	Ag-wh., shiny	3–3.5	13.75–14.1	....	Iso.	F. uneven
)	Fe-black	Blk.	5.5–6.5	5.17–5.18	5–5.5	Iso.; xls., mass.	F. uneven P. oct.
	Steel-gry. to Fe-blk.	Dk. red to brnh-red	5.5–6.5	4.9–5.3	5–5.5	Hex. rhom.	F. uneven P. bas. or rhom.
	Fe-blk.	Rdh-brn. to pur-plish-brn.	6–7	4.8–5.3	5–5.5	Iso.	F. conch. P. oct.

			Name.	Composition.
	Much H_2O in c.t.	Botryoidal, stalactitic, amorphous	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
		Prismatic xls.	**GOETHITE** (Göthite) T349 S247	FeO(OH)
		Rdh-blk.; st. dark rdh-brn.	**TURGITE** (Hydrohematite) T350 S245	$[(FeO(OH)]_2Fe_2$ (
Cu globule in r.f. on ch.		Cuprite submetallic luster; Tenorite in scales or earthy	**CUPRITE** T331 S206	Cu_2O
			Tenorite (Melaconite; Paramelaconite) T332 S209	CuO
W reac. after fus. w. soda Mag. w. little soda		Mn in soda bd. (Cp. hübnerite)	**WOLFRAMITE** T539 S982	$(Fe,Mn)WO_4$
		Little or no Mn reac.	**Ferberite** S985	$FeWO_4$
Mn in borax bd.		Slowly sol. in HCl w. a little gel. sil.	Braunite T343 S232	$3MnMnO_3.MnSiC$
Cb reac. after fus. w. borax		Mn in soda bd. Mag. w. little soda	**COLUMBITE** T490 S731	$(Fe,Mn)Cb_2O_6$
		Mn in soda bd.; U in s. ph. bd.	Samarskite T492 S739	$R''_3R'''_2(Nb,Ta)_6($ R'' = Fe, Ca, UO_2 R''' = Ce and Y met
Gel. sil. in HCl sol. on evaporation		Fus. w. much intumes. Insol. in HCl after fus.	**Allanite** (Orthite) T440 S522	$R''_2R'''_3(OH)(SiO$ R'' = Ca and Fe R''' = Al, Fe, & Ce m
		Strongly mag. after fus. Little intumes.	**Ilvaite** (Lievrite) T445 S541	$CaFe_2(FeOH)(SiC$
Te minerals Gently heated in conc. H_2SO_4 gives rdh-violet sol.	Fus. and wholly vol.	Wh. subl. near assay; grn. flame	**Tellurium** T275 S11	Te
	Ag globule in o.f.	May contain Au also	**Hessite** T289 S47	Ag_2Te (Au iso. w. Ag)
	Au w. soda on Ch. Us. w. some Ag (Continued next page)	Slightly sectile to brittle	**Petzite** T289 S48	$(Ag,Au)_2Te$
		Very brittle; cleavable. Krennerite decrepitates violently b.b.	**Sylvanite** T304 S103	$(Au,Ag)Te_2$
			Krennerite T305 S105	$(Au,Ag)Te_2$

	Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Dk. brn., blk., yel.	Yelh-brn.	5–5.5	3.6–4	5–5.5	Fibr.; mass.	F. splintery
	Yelh. or redh-brn. to blk.	Yelh-brn.	5–5.5	4–4.4	5–5.5	Orth.; us. prisms	C. pinac., per.
	Rdh-blk.	Dk. rdh-brn.	5.5–6	4.14–4.6	5–5.5	Botry.; incrust.	F. splintery
	Deep red	Brnh-red	3.5–4	5.85–6.15	2.5–3	Iso.	F. conch. or uneven
	Fe-gry. to blk.	Gryh-blk.	3–4	5.82–6.25	3	Mon.; mass.	C. basal, per. F. conch. to uneven
	Dk. gryh-blk. to brnh-blk.	Blk.	5–5.5	7.2–7.5	3–3.5	Mon.; us. xls.	C. pinac., per. F. uneven
	Blk.	Brnh-blk.	4–4.5	6.8–7.11	3.5	Mon.	C. pinac., per F. uneven
	Dk. brnh-blk. to steel-gry.	Brnh-blk. to steel-gry.	6–6.5	4.75–4.82	4.5–5	Tetr.	C. pyram., per. F. uneven
	Fe-blk. to brnh-blk.	Dk. red to blk.	6	5.3–7.3	5–5.5	Orth.; us. xls.	F. uneven
s1 ls	Velvet-blk.	Dk. rdh.-brn.	5–6	5.6–5.8	4.5–5	Orth.; us. mass.	F. conch.
)₂ als	Brn. to pitch-blk	Gry.	5.5–6	3–4.2	2.5	Mon.; us. mass.	F. uneven to conch.
)₂	Fe-blk.	Blk.	5.5–6	3.99–4.05	2.5	Orth.; us. prism.	F. uneven
	Sn-wh.	Sn-wh.	2–2.5	6.1–6.3	1	Hex. rhom.; us. mass.	C. prism., per.
	Steel-gry. to Pb-gry.	Gry.	2.5–3	8.3–8.5	1	Iso.; us. mass.	F. uneven
	Steel-gry. to Fe-blk.	Gry.	2.5–3	8.7–9.02	1.5	Massive	F. uneven
	Steel-gry. to Ag-wh.	Gry.	1.5–2	7.9–8.3	1	Mon.	C. pinac., per. F. uneven
	Ag-wh. to brass-yel.	Gry.	2.5	8.35	1	Orth.; us. prism.	C. basal, per.

			Name.	Composition.
		Very brittle; uneven to conchoidal fract.	**Calaverite** T305 S105	$(Au,Ag)Te_2$
	Bi w. soda on ch.	Red subl. on ch. w. "bismuth flux"	**Tetradymite** T284 S39	$Bi_2(Te,S)_3$
	Pb w. soda on ch.	$PbSO_4$ ppt. w. H_2SO_4 in HNO_3 sol.	Altaite T288 S51	PbTe
			Nagyagite T305 S105	Au, Pb, Sb, Te, S

SECTI

Strongly mag. before heating. (Cp. platinum, which is sometimes mag.)	Completely sol. in HCl; sol. reac. for both ferrous and ferric Fe. (Cp. ilmenite, below)	**MAGNETITE** (Magnetic Iron Ore; Lodestone) T339 S224	$FeFe_2O_4$ (Somet. Mg, Mn, Ti
	Malleable. Meteoric Fe and some terrestrial Fe contains Ni	**Iron** (Meteoric Iron) T281 S28	Fe (Us. w. some Ni)
Ti in s. ph. bd. w. Sn on ch.	Disting. by xln. and phys. properties; ilmenite somet. slightly mag.	**ILMENITE** (Menaccanite; Titanic Iron) T336 S217	$FeTiO_3$ (Often also Fe_2O_3: sor Mg)
		Pseudobrookite T343 S232	$Fe_4(TiO_4)_3$
Mn in soda bd.	Wh. ZnO subl. on intense ign. w. soda, borax, and powdered ch. on ch.; grn. w. $Co(NO_3)_2$	**FRANKLINITE** T341 S227	$(Fe,Zn,Mn)(Fe,Mn)_2O_4$
Little or no H_2O in c.t.	Sometimes slightly mag. before heating. Dif. fus.	**HEMATITE** (Specular Iron) T334 S213	Fe_2O_3
		Martite T336 S216	Fe_2O_3
H_2O in c.t. Dif. fus.	Mammillary, botryoidal, stalactitic, amorphous	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
	Us. prisms	**GOETHITE** (Göthite) T349 S247	FeO(OH)
	Us. decrepitates violently in c.t.	**Turgite** (Hydrohematite) T350 S245	$[FeO(OH)]_2Fe_2O_3$

	Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallisation.	Cleavage and Fracture.
	Pale bronze-yel.	Yelh-gry.	2.5	9.04	1	Massive	F. uneven
	Pale steel-gry.	Gry.	1.5–2	7.2–7.6	1.5	Hex. rhom.; us. bladed	C. basal., per. Laminæ flex.
	Sn-wh.; tar. bronze-yel.	Gry.	3	8.16	1.5	Iso.; us. mass.	C. cubic
	Dk. Pb-gry.	Dk. Pb-gry.	1–1.5	6.85–7.2	1.5	Orth.; us. fol.	C. pinac., per. Laminæ flex.

ON 5.

	Fe-blk.	Blk.	5.5–6.5	5.17–5.18		Iso.; xls., mass.	P. oct. F. uneven
	Steel-gry.	Steel-gry.	4–5	7.3–7.8		Iso.; us. mass.	C. cubic F. hackly
et.	Fe-blk.	Blk. to brnh-red	5–6	4.5–5		Hex. rhom.; us. plates or mass.	F. conch.
	Dk. brn. to blk.	Yelh. or rdh-brn.	6	4.4–4.98		Orth.	F. uneven
	Fe-blk.	Rdh-brn. to blk.	5.5–6.5	5.07–5.22		Iso.; gran., mass.	P. oct. F. uneven
	Steel-gry. to Fe-blk. Earthy, red	Cherry-rd brnh-red	5.5–6.5	4.9–5.3		Hex. rhom.	F. uneven, scaly, or fibr.
	Fe-blk.	Purplish or rdh-brn.	6–7	4.8–5.3		Iso.; us. xls.	P. oct. F. conch.
	Brn. to blk. Earthy, yel.	Yelh-brn. Yel. ocher	5–5.5	3.6–4		No xls.; us. mass. or fibr.	F. splintery
	Dk. brn. to blk.	Brnh-yel. to ocher-yel.	5–5.5	4.0–4.4		Orth.; us. prisms	C. pinac., per. F. uneven
	Blk. to rdh-blk.	Brnh-red	5.5–6	4.14–4.6		Mass. or mammil.	F. splint.

		Name.	Compositi
Little or no H_2O in c. t.	O in c.t.	**PYROLUSITE** T347 S243	MnO_2 (A little H_2O)
	Slowly sol. in HCl w. gel. sil.	**Braunite** T343 S232	$3MnMnO_3.MnSi$
	No gel. sil.	Hausmannite T342 S230	Mn_3O_4
Much H_2O in c.t.	Prismatic xls.; us. striated	**MANGANITE** T349 S248	MnO(OH)
	Amorphous; us. Ba reac. in HCl sol. Botry., reniform, stalactitic	**PSILOMELANE** T352 S257	$(H_2,Mn)_2MnO_3$
	Dull, earthy, frothy, powdery, or reniform and compact	**WAD** (Bog Manganese) T352 S257	MnO, MnO_2,H_2O (Often Fe, Si, Al, B

SECTI

Very soft. Soils fingers and marks paper easily	S and Mo reac. in o.t. Yel-grn. flame	**MOLYBDENITE** T285 S41	MoS_2
	No reac. in o.t. Very refractory b.b.	**GRAPHITE** (Plumbago; Black Lead) T273 S7	C
Cr in borax or s. ph. bd.	Mag. on intense ign. w. equal amt. of soda on ch. (except varieties with much Mg and Al)	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; Al a Fe''' iso. w. Cr)
Ti reac. in s. ph. bd. on ch. w. Sn; or in HCl sol. after fus. w. borax	Mag. on intense ign. w. equal amt. of soda on ch.	**ILMENITE** (Menaccanite; Titanic Iron) T336 S217	$FeTiO_3$ (Some Fe_2O_3 and M
	Submetallic to adamantine luster; us. prismatic xls.	**RUTILE** T345 S237	TiO_2 (Us. a little Fe)
	Similar to Rutile. Disting. by xl. habit and phys. properties. Brookite us. tabular xls.	**Octahedrite** T346 S240	TiO_2
		Brookite T347 S242	TiO_2
	Ca reac. in HCl sol. after fus. w. soda and precipitating Ti w. am.	**Perovskite** (Perofskite) T487 S722	$CaTiO_3$ (Fe iso. w. Ca)

ion.	Color.	Streak.	Hard-ness.	Specific Gravity.	Crystalliza-tion.	Cleavage and Fracture.
	Fe-blk.	Blk.	2–2.5	4.73–4.86	Pseudm., mass.	F. splint.
iO_2	Dk. brnh-blk. to steel-gry.	Brnh-blk.	6–6.5	4.75–4.82	Tetr.; us. pyram.	C. pyram., per. F. uneven
	Brnh-blk.	Chestnut-brn.	5–5.5	4.72–4.856	Tetr.; us. pyram.	C. basal F. uneven
	Steel-gry. to Fe-blk.	Rdh-brn. to blk.	4	4.2–4.4	Orth.; prism.	C. pinac., per. F. uneven
	Fe-blk.	Brnh-blk.	5–6	3.7–4.7	Massive	F. uneven
) Ba)	Bluish or brnh-blk. to dull blk.	Brnh-blk. to blk.	1–6	3–4.26	Amorph.	F. uneven

ION 7.

	Pb-gry.	Gryh-blk., grnh. on glazed paper	1–1.5	4.7–4.8	Hex.(?); fol.	C. basal, per.; flex.
	Fe-blk. to dk. steel-gry.	Gryh.-blk.	1–2	2.09–2.23	Hex. rhom.; fol.	C. basal, per.; flex.
and	Fe-blk. to brnh-blk.	Dk. brn.	5.5	4.32–4.57	Iso.; us. mass.	F. uneven
Mg)	Fe-blk.	Brnh-red to blk.	5–6	4.5–5	Hex. rhom.; us. mass. or plates	F. conch.
	Rdh-brn. to blk. and yelh.	Pale brn.	6–6.5	4.18–4.25	Tetr.; us. xls.	C. prism. F. uneven
	Brn. to dk. blue and blk.	Cols.	5.5–6	3.82–3.95	Tetr.; us. pyram.	C. basal and pyram. F. conch.
	Hair brn. to blk.	Cols. to gryh. or yelh.	5.5–6	3.87–4.08	Orth.; us. xls.	F. uneven
	Yel. and brn. to blk.	Cols. to gryh.	5.5	4.017–4.039	Iso.	C. cubic F. uneven

		Name.	Composition
Cb reac. after fus. w. soda or borax, dissolving in HCl, and boiling w. Sn	W. little soda becomes mag.; us. Mn reac. also	**COLUMBITE** T490 S731	$(Fe,Mn)Cb_2O_6$ (Ta iso. w. Cb; a Sn and W)
		Tantalite T490 S731	$(Fe,Mn)Ta_2O_6$ (Cb iso. w. Ta; Sn and W)
	Disting. by st. and dull exterior	**Fergusonite** T490 S729	$Y(Cb,Ta)O_4$ (Er, Ce, U iso. w.
	H_2O in c.t.; turns yel.	Yttrotantalite T492 S738	$(Ca,Fe)(Y,Er)(Ta,Cb)_4O_{15}.4H_2$ (Also us. Ce, U, an
U in s. ph. bd. Little or no Cb	Very heavy; sol. in dil. H_2SO_4 w. slight evolution of gas (He)	**Uraninite** (Pitchblende) T521 S889	Uranate of Pb a (Also Th, La, Y, C He, A, and us. I
Pt or metals of the Pt group [Cp. sperrylite (Sec. 1) and the black micas (Sec. 23)].	Malleable; b.b. unaltered; sometimes mag.	**Platinum** T280 S25	Pt (Us. w. Fe, Ir, Os)
	Slightly malleable to brittle; Os in o.t.	Iridosmine (Osmiridium) T280 S27	(Ir,Os) (Somet. Rh, Pt, Ru
	No reac. for Os	Iridium T280 S27	Ir (W. Pt, Os, etc.)

SECT

Burns w. blue flame and SO_2 fumes	Subl. in c.t. is red liquid while hot, yel. solid when cold	**SULPHUR** T273 S8	S (Us. clay, bitumen
As_2O_3 subl. on ch.; wh. xln., vol.; far from assay	Subl. in c.t. deep red, nearly blk. when hot; a rdh-yel. transp. solid when cold	**REALGAR** T282 S33	AsS
		ORPIMENT T282 S35	As_2S_3
	Vol. on ch.; As_2O_3, subl. in c.t.	Arsenolite T330 S198	As_2O_3
Sb_2O_3 subl. on ch.; dense wh. and near assay	SO_2 in o.t.	**Kermesite** T305 S106	Sb_2S_2O
	Easily fus. in c.t. w. slight wh. subl.	**Senarmontite** T330 S198	Sb_2O_3
		Valentinite T330 S199	Sb_2O_3

...a.	Color.	Streak.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
O little	Fe-blk. to gryh. and brnh-blk.	Dk. red to blk.	6	5.3–6.5		Orth.; us. prisms	F. uneven
O slight	Blk.	Blk.	6	6.5–7.3		Orth.	
r)	Brnh-blk.	Pale brn.	5.5–6	4.3–5.8		Tetr.; us. lamellar	F. uneven
D d W)	Yel. to brn. and blk.	Cols. to gry.	5–5.5	5.5–5.9		Orth.; us. prisms	F. conch.
nd U a. N. sI₂O)	Gryh., grnh., or brnh-blk.	Brnh-blk.	5.5	9–9.7		Iso.; us. mass.	F. conch., uneven
O	Whh.steel-gry.	Gry., shiny	4–4.5	14–19		Iso.; us. grains or scales	F. hackly
h)	Sn-wh. to lt. steel-gry.	Gry.	6–7	19.5–21.2		Hex. rhom.; us. flat grains	C. basal, per.
	Ag-wh., tinge of yel.	Gry.	6–7	22.6–22.8		Iso.	F. hackly

TION 8.

		Luster					
s, etc.)	Pale yel. to brnh. and grnh-yel.	Resinous	1.5–2.5	2.05–2.09	1	Orth. Figs. 56, 57	F. conch. to uneven
	Aurora-red & orange-yel.	Resinous	1.5–2	3.556	1	Mon.; us. xls.	C. pinac. F. conch.
	Lemon-yel.	C. pearly; resinous	1.5–2	3.4–3.5	1	Mon.; us. fol.	C. pinac., per.; striated; flex.
	Cols. to wh.	Vitreous or silky	1.5	3.70–3.72	1	Iso; us. capil.	F. uneven
	Cherry-red to brnh-red	Adamantine	1–1.5	4.5–4.6	1	Mon.; us. acic.	C. pinac., per.
	Cols. to wh. and gryh.	Resinous	2–2.5	5.22–5.3	1.5	Iso.	F. uneven
	Cols. to wh., rdh., or brnh.	Adamantine C. pearly	2.5–3	5.566	1.5	Orth.; us. prism.	C. pinac., per., also prism.

		Name.	Composition.
Hg subl. in c.t. w. soda that has been dried by previously heating nearly to redness	SO_2 and Hg in o.t.; blk. subl. in c.t.	**CINNABAR** T293 S66	HgS (Us. w. Fe_2O_3, clay, b men)
	Cl reac. w. $AgNO_3$ after soda fus.	Calomel T317 S153	Hg_2Cl_2
K or Na flame color; sol. in H_2O	Alkaline residue after ign.; wholly vol. only by prolonged heating	Section 16	

SECTI

CO_2 efferv. in warm dil. acids	In c.t. dark yel. while hot; us. decrepitates	**CERUSITE** T363 S286	$PbCO_3$
	In c.t. wh. $PbCl_2$ subl. which fus. to cols.	Phosgenite T364 S292	$(PbCl)_2CO_3$
	HCl sol. w. $BaCl_2$ gives wh. ppt. $BaSO_4$	Leadhillite T529 S921	$Pb_2(PbOH)_2(CO_3)_2S$
S. reac. in fus. w. soda; sol. in dil. HCl; $PbCl_2$ ppt. on cooling	Little or no H_2O in c.t.	**ANGLESITE** T527 S907	$PbSO_4$
	H_2O in c.t.; Cu reac. in HCl sol.	**Linarite** T530 S927	$[(Pb,Cu)OH]_2SO_4$
		Caledonite T530 S924	$[(Pb,Cu)OH]_2SO_4$
HNO_3 sol. reacts for P w. am. mol.	In c.t. slight wh. subl. $PbCl_2$	**PYROMORPHITE** T499 S770	$Pb_4(PbCl)(PO_4)_3$ (Often also Ca and A
As subl. in c.t. w. ch.	Wh. ppt. AgCl w. $AgNO_3$ in HNO_3 sol.	**Mimetite** T500 S771	$Pb_4(PbCl)(AsO_4)_3$ (Often also Ca and I
V in s. ph. bd.	Wh. ppt. AgCl w. $AgNO_3$ in HNO_3 sol.	**Vanadinite** T500 S773	$Pb_4(PbCl)(VO_4)_3$ (Somet. P and As)
	H_2O in c.t. Reacts for Zn. Cuprodescloizite contains Cu	**Descloizite** (Cuprodescloizite) T505 S787	(Pb,Zn)[(Pb,Zn)O V
Cr in s. ph. bd.	St. orange-yel.	**Crocoite** T529 S913	$PbCrO_4$
Mo in s. ph. bd. (in o.f. yelh-grn., in r.f. dark grn.)		**Wulfenite** T541 S989	$PbMoO_4$ (Ca somet. iso. w. Pb
Not included above. In o.f. on ch. fus. to yel. glass; in r.f. globule of metallic Pb without fluxes		Massicot T332 S209	PbO (Us. impure)

...	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
...tu-	Cochineal-red to brnh.	Adamantine	2–2.5	8.0–8.2	Vol. 1.5	Hex. rhom.	C. prism., per. F. uneven
	Cols., wh., or gry.	Adamantine	1–2	6.482	Vol. 1	Tetr.	F. conch. Sectile

...ON 9.

	Cols. to wh. and gry.	Adamantine	3–3.5	6.46–6.57	1.5	Orth.	F. conch.
	Cols., wh., gry. and yel.	Adamantine	2.75–3	6.0–6.3	1	Tetr.; us. xls.	C. prism. and basal
...O_4	Cols., wh., yel., grn., or gry.	C. pearly. Resinous	2.5	6.26–6.44	1.5	Mon.; us. tab.	C. basal, per. F. uneven
	Cols., wh., yelh., grnh.	Adamantine to vitreous	2.75–3	6.3–6.39	2.5	Orth.; us. xls.	C. basal and prism. F. conch.
...	Azure-blue	Vitreous	2.5	5.3–5.45	1.5	Mon.	C. pinac., per. F. conch.
...	Bluish-grn.	Resinous	2.5–3	6.40	1.5	Orth.	C. basal, per.
...s)	Grn., yel., brn. and wh.	Resinous	3.5–4	6.5–7.1	2	Hex.; us. prism.	F. uneven
...P)	Cols., yel., orange, brn.	Resinous	3.5	7.0–7.25	1.5	Hex.; us. prism.	F. uneven
...	Ruby-red, brn., yel.	Resinous	2.75–3	6.66–7.10	1.5	Hex.; us. prism.	F. uneven
...H] ...O_4	Brnh-blk. to red.	Greasy	3.5	5.9–6.2	1.5	Orth.; us. xls.	F. uneven
	Bright red	Adamantine to vitreous	2.5–3	5.0–6.1	1.5	Mon.; us. xls.	F. uneven
...)	Yel., orange-red, gry., wh.	Resinous to adamantine	2.75–3	6.7–7.0	2	Tetr.; us. tab.	C. pyram. F. uneven
	S-yel. to rdh-yel.	Dull	2	7.83–9.36	1.5	Mass., scaly	

		Name.	Composition.
Deep red col. (Hydrocuprite orange)	Strong sol. in HCl gives wh. ppt. Cu Cl when much diluted (a cuprous compound)	**CUPRITE** (Hydrocuprite) T331 S206	Cu_2O (OH in hydrocupri
CO_2 efferv. in HCl	H_2O in c.t. Disting. by color	**MALACHITE** T364 S294	$(CuOH)_2CO_3$
		AZURITE T365 S295	$Cu(CuOH)_2(CO_3)$
Blue flame col.	H_2O in c.t.	**Atacamite** T322 S172	$Cu(CuCl)(OH)_3$
S reac. in fus. w. soda	Much H_2O in c.t. Sol. in H_2O	**Chalcanthite** T534 S944	$CuSO_4.5H_2O$
	Acid H_2O on intense ign. in c.t.	**Brochantite** T530 S925	$[Cu(OH)_2]_3CuSO_4$
As fumes on ch.; As mirror w. ch. in c.t.; deflagrates on ch.	B.b. cracks and fus. Gel. $Al(OH)_3$ ppt. w. am. in HCl sol.	Liroconite T514 S853	$[CuAl(OH)_6]_3Cu_6A$ $(AsO_4)_5.20H$
	Globule xln. after fus. Euchroite much H_2O in c.t.; others little H_2O at red heat. Disting. by phys. properties	**Clinoclasite** T505 S795	$(CuOH)_3AsO_4$
		Olivenite T504 S784	$Cu(CuOH)AsO_4$
		Euchroite T511 S838	$Cu(CuOH)AsO_4 3H$
	Decrep. and gives much H_2O in c.t.; res. of olive-grn. scales	Chalcophyllite T511 S840	$Cu(OH)_2[(CuOH)_2$ $AsO_4]_2.10H_2$
P reac. w. am. mol.	U in s. ph. bd. Micaceous	**Torbernite** T515 S856	$Cu(UO_2)_2(PO_4)_2$-$.8H_2$
	H_2O and blackens in c.t.	**Libethenite** T504 S786	$Cu(CuOH)PO_4$

SECTIC

SO_2 fumes and wh. subl. of As_2O_3 or Sb_2O_3 in c.t. (Cp. polybasite)	Abund. subl. in c.t., deep red hot, rdh-yel. cold; slight S subl. above it	**Proustite** (Ruby Silver) T311 S134	Ag_3AsS_3
	Slight subl. in c.t., blk. hot, red-brn. cold; slight S subl. above it.	**Pyrargyrite** (Ruby Silver; Dark Red Silver Ore) T311 S131	Ag_3SbS_3 (Somet. As iso. w. Sb)

Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Ruby-red to rdh-blk. (Orange)	Adamantine to earthy	3.5–4	5.85–6.15	3	Iso. (Hydrocuprite earthy)	F. conch. or uneven
Bright grn.	Vitreous, silky, or dull	3.5–4	3.9–4.03	3	Mon.; us. botry.	C. basal, per. F. uneven
Azure-blue	Vitreous	3.5–4	3.77–3.83	3	Mon.; us. xls.	F. conch.
Emerald-grn.	Adamantine to vitreous	3–3.5	3.75–3.77	3–4	Orth.; us. prism.	C. pinac., per F. conch.
Deep azure-blue	Vitreous	2.5	2.12–2.30	3	Tri.	F. conch.
Deep emerald grn.	Vitreous	3.5–4	3.907	3.5	Orth.; us. xls.	C. pinac., per. F. uneven
Sky-blue to grnh.	Vitreous	2–2.5	2.882–2.985	3–3.5	Mon.; us. xls.	F. uneven
Dk. grn. to bluish-grn.	Vitreous; C. pearly	2.5–3	4.19–4.37	2–2.5	Mon.	C. basal, per.
Blkh-grn. to olive-grn. and brn.	Vitreous to adamantine	3	4.1–4.4	2–2.5	Orth.; us. prism.	F. conch. to uneven
Emerald-grn.	Vitreous	3.5–4	3.389	2–2.5	Orth.; us. prism.	F. uneven
Grass-grn.	Vitreous; C. pearly	2	2.4–2.66	2–2.5	Hex. rhom.; us. tab.	C. basal, per.
Emerald-grn. to apple-grn.	Vitreous; C. pearly	2–2.5	3.4–3.6	3	Tetr.; us. tab.	C. basal, per.; fol.
Dk-grn. to olive-grn.	Resinous	4	3.6–3.8	2–2.5	Orth.	F. uneven

N 11.

Scarlet to ruby-red. St. scarlet	Adamantine	2–2.5	5.55	1	Hex. rhom.; hemimor.	C. rhom. F. conch.
Dk.red to blk. St. purplish	Metallic adamantine	2.5	5.77–5.86	1	Hex. rhom.; hemimor.	C. rhom. F. conch.

		Name.	Composition.
Cl, Br, or I reac. w. powdered galena in c.t.	Subl. wh. both hot and cold	**Cerargyrite** (Horn Silver) T319 S158	AgCl (Somet. Hg iso. w. A
	Subl. yel. hot, wh. cold. Not disting. by bp. methods	**Embolite** T319 S159	Ag(Cl,Br)
		Bromyrite T319 S159	AgBr
	Subl. orange-red hot, lemon-yel. cold	Iodyrite T319 S160	AgI

SECTI

CO_2 efferv. in HCl	H_2O in c.t.	Bismutite T367 S307	$BiOBi(OH)_2CO_3$
Does not efferv.	No H_2O in c.t.	Bismite T330 S200	$Bi(OH)_3$ (Often Fe, etc.)

SECTI

CO_2 efferv. in hot HCl	Becomes blk. and mag. in c.t.	**SIDERITE** (Spathic Iron) T359 S276	$FeCO_3$ (Mg, Mn, Ca iso. w. 1
Dif. fus.; strongly mag. after heating in r.f.	Little or no H_2O in c.t.; st. red	**HEMATITE** T334 S213	Fe_2O_3 (Somet Ti and Mg)
		Martite T336 S216	Fe_2O_3
	H_2O in c.t. Earthy, mammillary, stalactitic	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
	Us. prismatic xls.	**GOETHITE** (Göthite) T349 S247	FeO(OH)
	Us. decrepitates in c.t.	**Turgite** (Hydrohematite) T350 S245	$[FeO(OH)]_2Fe_2O_3$

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
)	Pearl-gry. and grnh. to cols.	Resinous to ada-mantine	1–1.5	5.552	1	Iso.; us. mass.	F. uneven; sec-tile
	Grn. or yel.	Resinous to ada-mantine	1–1.5	5.31–5.81	1	Iso.; us. mass.	F. uneven; sec-tile
	Grn. or yel.	Resinous to ada-mantine	2–3	5.8–6.0	1	Iso.; us. mass.	F. uneven; sec-tile
	Yel. to grnh. and brnh.	Resinous to ada-mantine	1.5	5.6–5.7	1	Hex.; hemimor.	C. basal, per.; sectile

)N 12.

	Wh., grn., yel., gry.	Dull	4–4.5	6.86–7.67	1.5	Amorph., earthy	
	Wh., straw-yel. to grnh. and gryh.	Dull to ad-aman-tine		4.361		Hex. rhom.	C. basal, per.; scaly, earthy

)N 13.

e)	Lt. to dk. brn. and gry.	Vitreous; C. pearly	3.5–4	3.83–3.88	4.5–5	Hex. rhom.; us. xln.	C. rhom., per.
	Brnh-red to blk.	Dull	5.5–6.5	4.9–5.3	5–5.5	Earthy; reni-form	F. uneven to splint.
	Fe-blk.	Submetal-lic to dull	6–7	4.8–5.3	5–5.5	Iso.	P. oct. F. conch.
	Yelh-brn. to dk.brn.	Silky or dull	5–5.5	3.6–4.0	5–5.5	Fibr., mass.	F. splint.
	Yelh-or redh-brn. to blk.	Adaman-tine to dull	5–5.5	4–4.4	5–5.5	Orth.	C. pinac., per.
	Rdh-blk. St. dk. redh-brn.	Dull, silky to sub-metal.	5–6	4.14–4.6	5–5.5	Botry.; in-crust.	F. splint.

			Name.	Composition.
Sol. in cold H_2O; wh. ppt. $BaSO_4$ w. $BaCl_2$ in HCl sol. Acid H_2O in c.t.		Ferrous iron only	**Melanterite** (Copperas) T534 S941	$FeSO_4.7H_2O$ (Mg and Mn iso. w. F
		Ferric iron only; disting. by phys. characters	**Copiapite** T536 S964	$Fe_2(FeOH)_2(SO_4)_5.17H_2O$
			Coquimbite T535 S956	$Fe_2(SO_4)_3.9H_2O$ (Al iso. w. Fe)
		Ferric Fe only; K flame; little H_2O in c.t.	**Jarosite** T537 S974	$K[Fe(OH)_2]_3(SO_4)_2$ (Ni iso. w. K)
P reac. w. am. mol. ∴ Ferrous Fe	Mn in borax bd. Little or no H_2O in c.t.	Li flame. (Cp. lithiophylite)	**Triphylite** T496 S756	$LiFePO_4$ (Mn iso. w. Fe)
		F reac. w. $KHSO_4$	**Triplite** T502 S777	$R(RF)PO_4$ (R = Fe, Mn, Ca, Mg)
	Mn in borax bd.; H_2O in c.t.; exfoliates		**Childrenite** T513 S850	$FeAl(OH)_2PO_4.H_2O$ (Mn iso. w. Fe)
	Little or no Mn; whitens w. gentle heat in c.t.		**Vivianite** T508 S814	$Fe_3(PO_4)_2.8H_2O$
P reac. w. am. mol.; ferric Fe; H_2O in c.t.			Dufrenite T506 S797	$Fe_2(OH)_3PO_4$
As subl. in c.t. w.ch. fragment	Co in borax bd. after roasting; HCl sol. rose-red (Cp. annabergite, below)		**Erythrite** (Cobalt Bloom) T509 S817	$Co_3(AsO_4)_2.8H_2O$ (Ni, Fe, Ca iso. w. Co)
	Ni in borax bd. after roasting; HCl sol. grn. (Co may mask bd. reac. for Ni)		**Annabergite** (Nickel Bloom) T509 S818	$Ni_3(AsO_4)_2.8H_2O$ (Co iso. w. Ni)
	Ferric but no ferrous Fe; HCl sol. yel.; rdh-brn. ppt. w. am.		**Pharmacosiderite** T513 S847	$Fe(FeOH)_3(AsO_4)_3.6H_2O$
			Scorodite T509 S821	$FeAsO_4.2H_2O$

SECTIO

Micaceous, foliated, or scaly. (Cp. micaceous minerals. Section 23)	Gel. sil. w. HCl on evaporation	**LEPIDOMELANE** T470 S634	$(K,H)_2Fe_2(Fe,Al)_4(SiO_4)_5$
	Slightly sol. in HCl w. separation of SiO_2	**BIOTITE** (Black Mica) T467 S627	$(K,H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$
	Readily sol. in HCl w. separation of SiO_2; sol. reacts for Ti	**Astrophyllite** T487 S719	$R'_4R''_4Ti(SiO_4)_4$ (R' = K, Na, H; R'' = Fe, Mn, Mg, Ca (Zr iso. w. Si)

Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Apple-grn. to wh.	Vitreous	2	1.89–1.9	1 4.5–5	Mon.	C. basal, per. F. conch.
S-yel.	Pearly	2.5	2.103	4.5–5	Mon.; us. tab.	C. pinac.
Wh., yelh., brnh., violet	Vitreous	2–2.5	2.1	4.5–5	Hex. rhom.; us. xls.	F. uneven
Ocher-yel. to clove-brn.	Vitreous	2.5–3.5	3.15–3.26	4.5	Hex. rhom.; us. xls.	C. basal F. uneven
Lt. blue, grn. or gry.	Vitreous to resinous	4.5–5	3.49–3.56	1.5	Orth.; us. mass.	C. basal, per. and pinac.
Chestnut-brn. to blkh-brn.	Resinous	4.5–5	3.44–3.8	1.5	Mon.; us. mass.	C. 2 at right angles F. uneven
Yelh-brn. to brnh-blk.	Vitreous to resinous	4.5–5	3.18–3.24	4	Orth.; us. xls.	F. uneven
Blue, bluish-grn. to cols.	Vitreous; C. pearly	1.5–2	2.58–2.68	2–2.5	Mon.; us. prism.	C. pinac., per. F. splint.
Dull olive to blkh-grn.	Silky, weak	3.5–4	3.2–3.4	2.5	Orth. us. fibr.	F. splint.
Crimson to peach-red	Dull; vitreous; C. pearly	1.5–2.5	2.948	2	Mon.; us. prism.	C. pinac., per.; sectile
Apple-grn.	Vitreous	1.5–2.5		4	Mon; us. capil.	C. pinac., per. F. uneven, earthy
Grn., yel., brn.	Adamantine to greasy	2.5	2.9–3.0	1.5–2	Iso. tetrh.; us. xls.	F. uneven
Pale grn. or brn.	Vitreous	3.5–4	3.1–3.3	2–2.5	Orth.; us. xls.	F. uneven

N 14.

Blk. to grnh-blk.	Adamantine to pearly	3	3–3.2	4.5–5	Mon.	C. basal, per.; elastic
Grn. to grnh. or brnh-blk.	Splendent; C. pearly	2.5–3	2.7–3.1	5	Mon.	C. basal, per.; elastic
Bronze to golden yel.	Pearly to submetallic	3	3.3–3.4	2.5–3	Orth.	C. pinac., per.; brittle

		Name.	Composition.
Gel. imperfectly; iso. xls.	Mostly ferric Fe	**ANDRADITE** (Ca-Fe Garnet) T417 S442	$Ca_3Fe_2(SiO_4)_3$ (Fe, Mn, Mg, Ca iso: Ca; Al iso. w. Fe)
Gel.; much ferrous Fe	May be mag. from included magnetite	**Fayalite** T422 S456	Fe_2SiO_4
Gel. sil. w. HCl; both ferrous and ferric Fe	Fuses quietly	**Ilvaite** (Lievrite) T445 S541	$CuFe_2(FeOH)(SiO$
	Fus. w. intumes.	**Allanite** (Orthite) T440 S522	$R''R'''_3(OH)(SiO_4$ (R'' = Ca, Fe; R''' = Fe, Ce, La, Nd, Pr)
H_2S and gel. sil. w. HCl	ZnO subl. on ch. w. soda; grn. w. $Co(NO_3)_2$	Danalite T414 S435	$Gl_3R_2(RS)(SiO_4)_3$ (R = Mn, Fe, Zn)
	Mn in borax bd.; no Zn	Helvite T414 S434	$Gl_3R_2(RS)(SiO_4)_3$ (R = Mn, Fe)

SECTI

W reac. after fus. w. soda. Very heavy	Mn in soda bd.	**WOLFRAMITE** T539 S982	$(Mn,Fe)WO_4$
	Little or no Mn reac.	**Ferberite** S985	$FeWO_4$
Micaceous (Cp. micaceous minerals, Section 23)	Easily fus.; Li flame	Zinnwaldite T467 S626	$(K,Li)_3Fe(AlO)Al(F,OH)_2(SiO_4)$
	Dif. fus.	**BIOTITE** (Black Mica) T467 S627	$(K.H)_2(Mg,Fe)_2(Al,Fe)_2(SiO_4)_3$
Red; isometric	Sol. in HCl w. gel. after fus.	**ALMANDITE** (Fe-Al Garnet) T416 S441	$Fe_3Al_2(SiO_4)_3$ (Mn, Mg, Ca iso. w.
Quietly and dif. fus.	Us. bronzy, metalloidal luster; prism and cl. angles near 90°	**Hypersthene** T385 S348	$(Mg,Fe)_2SiO_3$
	Prism and cl. angles 54° and 126°; Fe chiefly ferrous; sometimes fibrous (asbestos)	**Anthophyllite** (Asbestos in part) T398 S384	$(Mg,Fe)SiO_3$ (Somet. also Al)
Fus. w. intumes.	Fused mass dk. brn. or blk.	**EPIDOTE** (Pistacite) T438 S516	$Ca_2(AlOH)(Al,Fe$ $(SiO_4)_3$

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
w.	Wine-red, grnh., yel., brn., to blk.	Vitreous to resi-nous	6.5–7.5	3.8–3.9	3.5	Iso.	F. uneven to conch.
	Yel. to dk. yelh-grn.	Metalloid-al, resi-nous	6.5	4–4.14	4	Orth.; us. mass.	C. pinac. F. uneven
ı)₂	Fe-blk.	Submetal-lic	5.5–6	3.99–4.05	2.5	Orth.; us. prism.	F. uneven
s ıl,	Brn. to pitch-blk.	Resinous to sub-metallic	5.5–6	3.0–4.2	2.5	Mon.; us. mass.	F. uneven to conch.
	Flesh-red to gry.	Vitreous to resinous	5.5–6	3.427	3	Iso. tetrh.; us. mass.	F. uneven
	Yel. to yelh. and redh-brn.	Vitreous to resinous	6–6.5	3.16–3.36	4–5	Iso. tetrh.; us. xls.	F. uneven

)N 15.

	Gryh. to brnh-blk.; st. blk.	Submetal-lic	5–5.5	7.2–7.5	4	Mon.; us. xls.	C. pinac. per. F. uneven
	Blk. St. brnh-blk.	Submetal-lic	4–4.5	6.8–7.11	3.5	Mon.	C. pinac. per. F. uneven
ı	Gry., yel., brn., violet	Pearly	2.5–3	2.8–3.2	2.5–3	Mon.	C. basal, per.; flex.
	Grn. to grnh. or brnh-blk.	Splendent C. pearly	2.5–3	2.7–3.1	5	Mon.	C. basal, per.; elastic
'e)	Deep red to brnh-blk.	Vitreous	6.5–7.5	3.9–4.2	3	Iso.	F. uneven to conch.
	Grnh-blk. to brn. and bronze	Pearly to bronzy	5–6	3.4–3.5	5	Orth.; us. mass.	C. pinac. per. F. uneven
	Gry., clove-brn., grn.	Vitreous C. pearly	5.5–6	3.1–3.2	5–6	Orth.; us. fibr. or mass.	C. prism. per.
₂	Yelh. to blkh-grn. and gry.	Vitreous	6–7	3.25–3.5	3–4	Mon.; us. prism.	C. basal, per. F. uneven

		Name.	Composition.
Fus. w. intumes.; Na flame	Prism and cl. angles 54° and 126°; Fe chiefly ferrous	Arfvedsonite T405 S401	$[(Na,K)_2,Ca,Fe]SiO_3$ (Some $(Al,Fe)_2O_3$)
	Both ferrous and ferric Fe. Crocidolite is us. fibrous	Crocidolite T404 S400	$NaFe'''(Fe'',Mg)(SiO_3)_2$
		Riebeckite T404 S400	$Na_2Fe'''_2(Fe'',Ca)(SiO_3)_5$
Na flame; fus.quietly	Prism and cl. angles near 90°	**Acmite** (Aegirite) T391 S364	$NaFe'''(SiO_3)_2$
Compare pyroxene, amphibole, tourmaline, chloritoid, and ottrelite, some of the dark green and black varieties of which contain sufficient iron to make them magnetic upon ignition.			

SECTIO

Make flame tests below with Pt wire. Most minerals give some yellow color to the flam yellow. The violet flame of K is purplish-

			Name	Composition
Wh. AgCl ppt. w. HNO_3 and $AgNO_3$	Wh. $BaSO_4$ ppt. in H_2O sol. w. HCl and $BaCl_2$	K flame	Kainite T530 S918	$MgSO_4.KCl.3H_2O$
		Na flame	Hanksite T530 S920	$9Na_2SO_4.2Na_2CO_3.KCl$
	Intense Na flame; no S		**HALITE** (Rock Salt; Common Salt) T318 S154	NaCl (Us. also Ca and Mg)
	K flame; no S	Little or no H_2O in c.t.	**SYLVITE** T318 S156	KCl (Na iso. w. K)
		Much H_2O in c.t.	**Carnallite** T323 S177	$KMgCl_3.6H_2O$
CO_2 efferv. w. HCl. H_2O sol. gives alkaline reac. w. turmeric paper	Sol. in H_2O of xln. if gently heated in c.t. ($H_2O=63\%$)		**Natron** (Sal Soda) T366 S301	$Na_2CO_3.10H_2O$
	H_2O and CO_2 when gently heated in c.t.		**Trona** T367 S303	$Na_2CO_3\cdot HNaCO_3\cdot 2H_2O$

Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
Blk.; st. dk. bluish-gry.	Vitreous	6	3.44–3.45	2.5	Mon.; us. prism.	C. prism., per. F. uneven
Leek-grn. to deep laven-der-blue	Silky, dull	4	3.2–3.3	3.5	Fibrous	Fibrous
Blk.	Vitreous	6	3.433	3?	Mon.	C. prism., per.
Grnh. to brnh-blk.	Vitreous	6–6.5	3.50–3.55	3.5	Mon.; prism.	C. prism. F. uneven

N 16.

:, but those containing Na as an essential constituent give an intense and persistent ed when seen through dark blue glass.

Cols., wh. to redh.	Vitreous	2.5–3	2.067–2.188	1.5–2	Mon.	C. pinac.
Cols., wh. to yelh.	Vitreous	3–3.5	2.562	1.5	Hex.; us. xls.	C. basal F. uneven
Cols., wh., redh., bluish	Vitreous	2.5	2.13	1.5	Iso.; us. cubic	C. cubic, per. F. conch.
Cols., wh., redh., bluish	Vitreous	2	1.97–1.99	1.5	Iso.	C. cubic, per.
Cols., wh., redh.	Vitreous to greasy	1	1.6	1–1.5	Orth.; us. mass.	F. conch.
Cols., gry., wh., yelh.	Vitreous	1–1.5	1.42–1.46	1	Mon.	C. basal F. conch.
Cols., gry., wh., yelh.	Vitreous	2.5–3	2.11–2.14	1.5	Mon.	C. pinac., per. F. uneven

		Name.	Composition.
Sulphates.—H_2O sol. w. HCl and $BaCl_2$ gives wh. ppt. $BaSO_4$	Na flame; little or no H_2O in c.t.	**Thenardite** T523 S895	Na_2SO_4
	B.b. swells and gives K flame; H_2O sol. w. HCl and am. gives gel. ppt. of $Al(OH)_3$	**Kalinite** (Potash Alum) T535 S951	$KAl(SO_4)_2.12H_2O$
	Mg reac. w. $Co(NO_3)_2$ on ch.	**Epsomite** (Epsom Salt) T533 S938	$MgSO_4.7H_2O$
	Intense Na flame; much H_2O in c.t.	**Mirabilite** (Glauber Salt) T531 S931	$Na_2SO_4.10H_2O$
Nitrates.—Deflagrates on ch.; NO_2 fumes w. $KHSO_4$ in c.t.	Intense Na flame	**SODA NITER** T517 S870	$NaNO_3$
	K flame	**NITER** (Saltpeter) T517 S 871	KNO_3
	H_2O in c.t.; deliquescent before ign., not after	Nitrocalcite T517 S872	$Ca(NO_3)_2.nH_2O$
B reac. w. turmeric paper	Swells and fus. to clear glass	**BORAX** T520 S886	$Na_2B_4O_7.10H_2O$

SECT

Make flame tests below with Pt wire and HCl.

CO_2 efferv. in dil. HCl	No H_2O in c.t.; Ba flame		**WITHERITE** T362 S284	$BaCO_3$
	H_2O in c.t.; alkaline sol. in boiling H_2O		**Gay-Lussite** T366 S301	$Na_2Ca(CO_3)_2.5H$
S reac. w. soda on ch.	Much H_2O in c.t. Readily sol. in hot dil. HCl	Sol. in hot H_2O; no decided flame col.	**GYPSUM** (Selenite; Alabaster) T531 S933	$CaSO_4.2H_2O$
		K flame; Mg reac. w. Na phosphate	**Polyhalite** T535 S950	$K_2Ca_2Mg(SO_4)_4.2H_2O$
	Little or no H_2O in c.t. (Continued next page)	Na flame; sol. in HCl	**Glauberite** T523 S898	$Na_2Ca(SO_4)_2$
		No flame col.; slowly sol. in hot dil. HCl	**ANHYDRITE** T528 S910	$CaSO_4$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., wh., brnh.	Vitreous	2–3	2.68–2.69	1.5–2	Orth.	C. basal F. uneven
	Cols. or wh.	Vitreous	2–2.5	1.75	1	Iso. pyr.; us. fibr.	F. conch.
	Cols. or wh.	Vitreous; earthy	2–2.5	1.751	1	Orth.; us. fibr.	C. pinac., per. F. conch.
	Cols. or wh.	Vitreous	1.5–2	1.481	1.5	Mon.; us. crusts	C. pinac., per.
	Cols. or wh.	Vitreous	1.5–2	2.24–2.29	1	Hex. rhom.; us. incrust.	C. rhom., per.
	Cols. or wh.	Vitreous; silky	2	2.09–2.14	1	Orth.; us. acic.	C. prism., per. F. uneven
	Wh. or gry.	Silky			2	Fibrous	Fibrous
	Cols., wh., gryh.	Vitreous to resinous	2–2.5	1.69–1.72	1–1.5	Mon.; us. prism.	C. pinac., per. F. conch.

ON 17.

	Cols., wh., yelh., gryh.	Vitreous	3–3.75	4.27–4.35	2	Orth.; twinned	F. uneven
)	Cols., wh., yelh., gryh.	Vitreous	2–3	1.93–1.95	1.5	Mon.; us. xls.	C. prism. F. conch.
	Cols., wh., yel., red., gry.	Vitreous C. pearly	1.5–2	2.31–2.33	3–3.5	Mon., Figs. 60, 61	C. 3 directions, pinac., per.
	Brick-red to yel.	Vitreous to resinous	2.5–3	2.77–2.78	1.5	Mon.; fibr., lamel.	C. pinac., F. splint.
	Cols., wh., yelh., gryh.	Vitreous	2.5–3	2.70–2.85	1.5–2	Mon.; us. tab.	C. basal, per. F. conch.
	Cols., wh., blue, gry., red	Vitreous; basal cl., pearly	3–3.5	2.90–2.99	3	Orth.; us. mass.	C. pinac., per. 3 directions at 90°

			Name.	Composition.
		Sr flame; nearly insol. in HCl	**CELESTITE** T526 S905	$SrSO_4$ (Somet. Ca and Ba)
		Ba flame; nearly insol. in HCl	**BARITE** (Heavy Spar) T524 S899	$BaSO_4$ (Somet. Ca and Sr)
F reac. w. $KHSO_4$ and glass in c.t.	Little or no H_2O in c.t.	Na flame; easily fus.	**CRYOLITE** T321 S166	Na_3AlF_6
		Ca flame; often phosphoresces and decrepitates in c.t.	**FLUORITE** (Fluor Spar) T320 S161	CaF_2 (Somet. Cl iso. w. F)
	Acid H_2O in c.t. Often etches glass and deposits sil.	Stout prisms; us. decrepitates	Thomsenolite T323 S180	$NaCaAlF_6.H_2O$
		Slender prisms; us. decrepitates	Pachnolite T323 S179	$NaCaAlF_6.H_2O$

SECTIO

				Name	Composition
P reac. w. am.mol.	Slight F reac. w. $KHSO_4$ in c.t.	$CaSO_4$ ppt. w. H_2SO_4 in HCl sol.	No H_2O in c.t.	**APATITE** T497 S762	$Ca_4(CaF)(PO_4)_3$ (Cl iso. w. F. Rare Mn)
			A little H_2O HF vapor in c.t.	Herderite T503 S760	$Ca[Gl(OH,F)]PO_4$
		No Ca	Little or no H_2O	Wagnerite T502 S775	$Mg(MgF)PO_4$
	Mn in soda bd.	Li flame	(Cp. triphylite)	**Lithiophylite** T496 S756	$LiMnPO_4$ (Fe iso. w. Mn)
		H_2O in c.t.	No flame color	Purpurite Ap. II, 83	$2(Fe,Mn)PO_4.H_2O$
	U in s.ph. bd.	$CaSO_4$ ppt. w. dil. H_2SO_4 in HCl sol.		**Autunite** T515 S857	$Ca(UO_2)_2(PO_4)_2.8H_2O$
B reac. w. turmeric paper	Na flame	Swells, sol. in H_2O		**BORAX** T520 S886	$Na_2B_4O_7.10H_2O$
(Continued next page)		Ca reac. w. am. oxalate		**Ulexite** (Boronatrocalcite) T520 S887	$NaCaB_5O_9.8H_2O$

Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
Cols., wh., blue, red	Vitreous to pearly	3–3.5	3.95–3.97	3	Orth., Fig. 59	C. basal, per. and prism.
Cols., wh., blue, yel., red, brn.	Vitreous to pearly	2.5–3.5	4.3–4.6	3	Orth.	C. basal, per. and prism.
Cols., wh., brnh.	Vitreous to greasy	2.5	2.95–3	1.5	Mon.; us. mass.	C. pinac. F. uneven
Cols., violet, blue, grn., yel., pink	Vitreous	4	3.01–3.25	3	Iso.; us. cubes.	C. oct., per. F. uneven
Cols., wh., redh.	Pearly to vitreous	2	2.93–3	1.5	Mon.; xls. and mass.	C. basal, per. F. uneven
Cols. or wh.	Vitreous	3	2.93–3	1.5	Mon.; prism.	F. uneven

N 18.

ely	Grn., blue, violet, red, brn., cols.	Vitreous to greasy	4.5–5	3.17–3.23	5–5.5	Hex.	C. basal F. uneven
	Wh. to pale grn. or yel.	Vitreous to resinous	5	2.99–3.01	4	Mon.	F. uneven
	Pale yel., gry. or red	Vitreous	5–5.5	3.07–3.14	3.5–4	Mon.	F. uneven and splint.
	Salmon-color clove-brn.	Vitreous to resinous	4.5–5	3.42–3.56	1.5	Orth.; us. mass.	C. basal, per. and pinac.
	Deep red or redh-purple	Silky	4–4.5	3.40	3–4	Orth.(?); us. mass.	C. pinac. F. uneven
	Lemon-yel. to S-yel.	Adamant. C. pearly	2–2.5	3.05–3.19	2.5	Orth.; tabular	C. basal, per. brittle
	Cols., wh., gryh., bluish, grnh.	Vitreous to resinous	2–2.5	1.69–1.72	1–1.5	Mon.; us. prism.	C. pinac., per. F. conch.
	Wh.	Silky	1	1.65	1	Fibrous	

			Name.	Composition
	B flame	No H_2O in c.t.; Cl reac. after fus. w. soda	**Boracite** T518 S879	$Mg_7Cl_2B_{16}O_{30}$
		Slowly vol.; sol. in H_2O	Sassolite (Boric Acid) T352 S255	$B(OH)_3$
		Mn in borax bd.	Sussexite T518 S876	H(Mn,Mg,Zn)B
		Exfoliates; Ca reac. w. am. oxalate	**Colemanite** T519 S882	$HCa(BO_2)_3.2H_2($
Mo reac. in s.ph. bd. or H_2SO_4; H_2O in c.t.; on ch. fus. and MoO_3 subl.			Molybdite T330 S201	$Fe_2(MoO_4)_3.7H_2($
V in s.ph. bd.; H_2O in c.t.; fus. easily to blk. non-mag. slag			**Carnotite** S. Ap. I	K, U, Ca, Ba va date
As subl. w. soda and ch. in c.t.	ZnO subl. w. soda on ch.; H_2O in c.t.		**Adamite** T505 S786	$Zn(ZnOH)AsO_4$
	$CaSO_4$ ppt. w. H_2SO_4 in conc. HCl sol.		Pharmacolite T510 S827	$HCaAsO_4.2H_2O$

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Fus. to cols. glass	Intumes.; B flame; H_2O in c.t.	DATOLITE T435 S502	$Ca(BOH)SiO_4$
	Intumes.; blebby glass; whitens in c.t.; CO_2 efferv. in warm dil. HCl	**Cancrinite** T411 S427	$H_6Na_6Ca(NaCO_3$ $Al_3(SiO_4)_9$
	Fus. quietly; whitens in c.t.; little or no Ca after separating Si and Al	NATROLITE T461 S600	$Na_2Al(AlO)(SiO_3$; $2H_2O$
Fus. dif. and whitens	**ZnO subl. w. soda on ch.; grn. w. $Co(NO_3)_2$**	CALAMINE (Hemimorphite; Smithsonite) T446 S546	$(ZnOH)_2SiO_3$

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
	Cols., wh., yel., gry., grn.	Vitreous	7	2.9–3.0	2	Iso. tetrh.; us. xls.	F. conch.
	Cols., wh., yel., gry.	Pearly	1	1.48	0.5	Tri.; us. tab.	C. basal, per. Unctuous
)₃	Wh., yelh., pinkish	Silky	3	3.42	2	Orth.(?); fibr.	F. splint.
	Cols., wh., yelh., gryh.	Vitr. to adamant	4–4.5	2.42	1.5	Mon.	C. pinac., per. F. uneven
	Straw-yel. to wh.	Silky to adamant.; C. pearly	1–2	4.50	2	Orth. and earthy	C. basal
ıa-	Canary-yel.	Dull			2.5	Hex.(?); us. earthy	
	Grnh., yelh., redh., vio-let, cols.	Vitreous	3.5	4.34–4.35	3	Orth.	C. prism. F. uneven
	Wh., gryh., redh.	Vitr. to pearly	2–2.5	2.64–2.73	2.5	Mon.; us. fibr.	C. pinac., per. F. uneven

ON 19.

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
	Cols., grnh., yelh., redh.	Vitreous	5–5.5	2.9–3.0	2–2.5	Mon.; us. xls.	F. conch. to uneven
₂	Yel., pink, grnh., blu-ish, gry., wh.	Vitr. to greasy	5–6	2.42–2.50	2	Hex.; us. mass.	C. prism. F. uneven
ı.	Cols., wh., yelh., redh., grnh.	Vitr. to pearly	5–5.5	2.20–2.25	2	Orth.; prism.	C. prism., per. F. uneven
	Wh., grnh., bluish, yelh., brnh.	Vitr. to adamant.	4.5–5	3.40–3.50	6	Orth.; hemi-morph.	C. prism., per. F. uneven

		Name.	Composition.
Contain Si, Al, and Ca. See Silicon (2)	Easily sol. in HCl; Na flame	**NEPHELITE** (Elaeolite; Nepheline) T409 S423	Approx. NaAlSiO (Some K and Ca)
	Dif. sol. in HCl; Na flame w. powdered gypsum	**ANORTHITE** (Lime Feldspar) T380 S337	$CaAl_2(SiO_4)_2$
	Fus. w. intumes. to dark slag	**Allanite** (Orthite) T440 S522	$R_2''R_3'''(OH)(SiO$ (R'' = Ca, Fe; R''' = Fe, Ce, Nd, Pr)
	Fus. w. slight intumes. to grnh. or yelh. glass	**Melilite** T426 S474	$Na_2(Ca,Mg)_{11}(Al,Fe)_4(SiO_4)_9$
Not included above	Swells and cracks apart on ign.; often glows	**Gadolinite** T436 S509	$Be_2Fe(YO)_2(SiO_4)$

Micaceous; flex., but not elastic, or little so	Exfoliates greatly b.b. Hydrated mica	**Vermiculite** (Jefferisite) T476 S664	Hydrous Mg-Al si-cate (Also Fe; somet. Na,
Dif. fus.; little or no Al or Ca; much Mg. See Silicon (2)	U. compact grnh. mass.; sometimes fibrous (chrysotile, commercial "asbestos") or foliated (marmolite)	**SERPENTINE** (Chrysotile; Marmolite) T476 S669	$H_4(Mg,Fe)_3Si_2O_9$ (Somet. Ni, iso. w.
	Somewhat like a gum or resin	**Deweylite** (Gymnite) T479 S676	$H_4Mg_4(SiO_4)_3.2H$ (Somet. Ni iso. w. M
	Compact, fine earthy texture; when dry floats on H_2O	Sepiolite (Meerschaum) T480 S680	$H_4Mg_2Si_3O_{10}$ (Somet. Cu and Ni)
Contains Ca but no Al. See Silicon (2)	Fus. w. intumes. to vesic. enamel; K flame; H_2O in c.t. (16%)	**APOPHYLLITE** T452 S566	$2H_7KCa_4(SiO_3)_8.9H_2O$
	Fus. quietly to wh. enamel; Na flame; little H_2O in c.t. (3%)	**Pectolite** T395 S373	$HNaCa_2(SiO_3)_3$
Becomes opaq. and fus. quietly to clear glass	Na flame; iso., us. trapezohedrons	**ANALCITE** T460 S595	$NaAl(SiO_3)_2.H_2O$
Fus. w. intumes. to blebby enamel	Little H_2O in c.t.; slowly and dif. sol. in HCl	**PREHNITE** T442 S530	$H_2Ca_2Al_2(SiO_4)_3$ (Fe iso. w. Al)

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., gry., grnh., redh., yelh.	Vitr. to greasy	5.5–6	2.55–2.65	3.5	Hex.; hemimorph.	C. prism. F. uneven
	Cols., wh., gry., redh.	Vitreous	6–6.5	2.74–2.76	4.5	Tri.	C. basal, per. and pinac. F. uneven
)₃ Al,	Brn. to blk.	Res., vitr. to submet.	5.5–6	3.0–4.2	2.5	Mon.; us. mass.	F. uneven to conch.
	Grn., yel., brn., wh.	Vitr. to res.	5	2.9–3.1	3	Tetr.; us. xls.	C. basal F. uneven
	Grnh. to brnh-blk.	Vitr. to greasy	6.5–7	4.0–4.5	5	Mon.	F. conch., splint.

ON 21.

ili- K)	Yel., brn., lt. to dk. grn.	Pearly	1–1.5	2.2–2.3	3.5	Mon. (?); fol.	C. basal, per.
Ig)	Olive to blkh-grn., yelh-grn., wh.	Greasy, wax-like, silky	2.5–5 Us. 4	2.5–2.65	5–5.5	Mass.; pseudm.	F. uneven, splint.
O g)	Yel., brn., wh. apple-grn.	Res.	2–3.5	2.0–2.2	4–5	Amorph.	F. uneven, conch.
	Wh. to gryh-wh.	Dull	2–2.5	2.0	5–5.5	Compact; earthy	F. uneven
	Wh., grnh., yelh., redh.	Vitreous; C. pearly	4.5–5	2.3–2.4	1.5	Tetr.; us. xls.	C. basal, per. F. uneven
	Cols., wh., gry.	Vitr., silky. C. pearly	5	2.68–2.78	2.5–3	Mon.; us. acic.	C. pinac., per. F. splint.
	Cols., wh., yelh., redh.	Vitreous	5–5.5	2.22–2.29	2.5	Iso; us. xls.	F. uneven
	Apple-grn., gry., wh.	Vitreous	6–6.5	2.80–2.95	2	Orth.; us. reniform or globular	F. uneven

		Name.	Composition.
Much H_2O in c.t.; contain Al and Ca or Ba See Silicon (2)	Ba reac. w. dil. HCl sol.	**Harmotome** T456 S581	$H_2(Ba,K_2)Al_2(SiO_3)_5$. $4H_2O$
	Rhom.; fus. w. swelling. Gmelinite often cracks and splits before fus.	**CHABAZITE** T458 S589	$(Ca,Na_2)Al_2(SiO_3)_4$. $6H_2O$ (Somet. K, Ba, Sr)
		Gmelinite T459 S593	$(Na_2,Ca)Al_2(SiO_3)_4$. $6H_2O$
	Fus. w. swelling and intumes. Stilbite us. sheaf-like and radiated; xls. seem orth. Cleav. faces of heulandite pearly luster and us. lozenge-shaped	**STILBITE** (Desmine) T456 S583	$H_4(Ca,Na_2)Al_2(SiO_3)_6.4H_2O$
		HEULANDITE T454 S574	$H_4(Ca,Na_2)Al_2(SiO_3)_6.3H_2O$
	Whitens and fus. without swelling to vesic. enamel; K flame with powdered gypsum	Phillipsite T455 S579	$2(Ca,K_2,Na_2)Al_2(SiO_3)_4.9H_2O$

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Ti reac. in s.ph. bd. w. Sn on ch.	Fus. w. intumes. to dk. glass	**TITANITE** (Sphene) T485 S712	$CaTiSiO_5$ (Some Fe; somet. Mn
Fus. quietly to glassy globule, slowly sol. in HCl	Us. striated on best cl.; often brilliant play of color	**LABRADORITE** (Ca-Na Feldspar) T379 S334	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($n : m = 1 : 1$ to $1 : 3$)
Fus. dif. to wh. globule; rather easily sol. in HCl	HCl sol. gives no Al ppt. w. am.; but Ca reac. w. am. oxalate	**WOLLSATONITE** T394 S371	$CaSiO_3$
Fus. w. intumes. to vesic. glass	Cl reac. w. $AgNO_3$; slowly sol. in acids; Na flame	**WERNERITE** (Scapolite) T425 S468	$n(Ca_4Al_6Si_6O_{25})$ $m(Na_4Al_3Si_9O_{24}Cl)$ $n : m = 3 : 1$ to $1 : 2$)
	Little or no Cl; easily sol. in acids	**Meionite** T425 S467	$Ca_4Al_6Si_6O_{25}$ (Us. some Na)

Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystallization.	Cleavage and Fracture.
Wh., gry., yel., red, brn.	Vitreous	4.5	2.44–2.50	3.5	Mon.; us. twinned	C. pinac. F. uneven
Wh., yel., flesh-red	Vitreous	4–5	2.08–2.16	3	Hex. rhom.; xls. nearly cubic	C. rhom. F. uneven
Wh., yel., flesh-red, grnh.	Vitreous	4.5	2.04–2.17	2.5	Hex. rhom.; us. xls.	C. prism. F. uneven
Wh., yel., brn., red	Vitreous; C. pearly	3.5–4	2.1–2.2	2–2.5	Mon.; twinned	C. pinac. per. F. uneven
Wh., yel., gry., red, brn.	Vitreous; C. pearly	3.5–4	2.18–2.22	2–2.5	Mon.	C. pinac. per. F. uneven
Wh., redh.	Vitreous	4–4.5	2.2	3	Mon.; twinned	C. pinac. F. uneven

N 22.

Gry., brn., yel., grn.	Res. to adamant	5–5.5	3.4–3.56	3	Mon.; us. xls.	C. prism. F. uneven
Wh., gry., brn., grn.	Vitr. to pearly	5–6	2.70–2.72	3–4	Tri.; us. mass.	C. basal, per. & pinac. F. uneven
Cols., wh., gry., yel., red, brn.	Vitreous; C. pearly	4.5–5	2.8–2.9	4	Mon.; us. mass.	C. pinac., per. F. uneven
Wh., gry., grnh., bluish, redh.	Vitr. to pearly	5–6	2.66–2.73	3	Tetr.	C. prism. and pinac. F. uneven
Cols. to wh.	Vitreous	5.5–6	2.7–2.74	4	Tetr.	C. prism and pinac. F. uneven

			Name.	Composition.
Micaceous or foliated	Li flame; foliæ elastic	Easily fus. to wh. or gry. globule; acid H_2O in c.t. on intense ign.	**LEPIDOLITE** (Lithia Mica) T467 S624	$LiK[Al(OH,F)_2]A$ $(SiO_3)_3$
		Easily fus. to dark globule	Zinnwaldite T467 S626	$(K,Li)_3Fe(AlO)$ $[Al(F,OH)_2]Al(Si$
		Exfoliates greatly; fus. w. dif.; much H_2O in c.t.	**Cookeite** T467 S625	$Li[Al(F,OH)_2]$ $(SiO_3)_2$
	Decomposed by boiling conc. H_2SO_4. (Foliæ lose luster and transp. and acid becomes turbid); foliæ elastic, except chlorite and kämmererite	Us. dk. col.; often w. quartz and feldspar and in igneous rocks.	**BIOTITE** (Black Mica) T467 S627	$(K,H)_2(Mg,Fe)_2$ $(Al,Fe)_2(SiO_4)$
		Gel. w. HCl.	**LEPIDOMELANE** T470 S634	$(K,H)_2Fe_3(Fe,Al)$ $(SiO_4)_5$
		Lt. to dk. col.; us. in xln. limestone; much more readily decomposed than biotite	**PHLOGOPITE** (Magnesia Mica) T469 S632	$[H,K,Mg(F,OH)]$ $Mg_3Al(SiO_4)_3$ (A little Fe iso. w. and Al)
		Foliæ flex. but not elastic; much H_2O	**CHLORITE** (Clinochlore, Penninite, Prochlorite) T472 S643	$H_8(Mg,Fe)_5Al_2Si_3$ (Often a little Cr)
		Col. rdh.; Cr in borax bd.	Kämmererite (Chrome Chlorite) T474 S652	$H_8(Mg,Fe)_5(Al,C$ Si_3O_{18}
	Not decomposed by boiling conc. H_2SO_4. (Flakes retain luster and transp., acid remains clear)	Common lt. colored mica; elastic; us. w. quartz and feldspar. Fine scaly us. soapy feel, damourite, sericite, hydromica	**MUSCOVITE** (Potash Mica, Damourite; Sericite, Hydromica) T464 S614	$H_2KAl_3(SiO_4)_3$ (Fe iso. w. Al)
		Na flame	Paragonite (Soda Mica) T467 S623	$H_2NaAl_3(SiO_4)_3$
		Soft; greasy feel; foliæ flex. but not elastic (cp. muscovite, above)	**TALC** (Steatite, Soapstone) T479 S678	$H_2Mg_3(SiO_3)_4$
		Foliæ brittle; harder than true micas	**Margarite** (Brittle Mica) T470 S636	$H_2CaAl_4Si_2O_{12}$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
l	Lilac, gryh-wh., redh., yelh.	Pearly	2.5–4	2.8–2.9	2–2.5	Mon.; us. gran. or scaly	C. basal, per.
b)s	Gry., brn., yel., violet	Pearly	2.5–3	2.82–3.2	2–2.5	Mon.	C. basal, per.
	Wh. to yelh-grn.	Pearly	2.5	2.70	4.5–5	Mon.; us. scaly	C. basal, per.
l	Grn., yel., brn., blk.	Splendent to pearly and submet.	2.5–3	2.7–3.1	5	Mon.	C. basal, per.
l	Blk. to grnh-blk.	Adamant to pearly	3	3–3.2	4.5–5	Mon.	C. basal, per.
l- Ig	Yelh-brn., grn., wh., cols.	Pearly to submet.	2.5–3	2.78–2.85	4.5–5	Mon.	C. basal, per.
hs	Grn. of various shades	Vitr. to pearly	1–2.5	2.6–2.96	5–5.5	Mon.	C. basal, per.
ls-	Rose-red to deep red	Vitr. to pearly	2–2.5	2.65–3.1	5–5.5	Mon.	C. basal, per.
	Wh., gryh., yelh., grnh., brnh.	Vitr. to pearly	2–2.5	2.76–3	4.5–5	Mon.	C. basal, per.
	Yelh., grnh., gryh-wh.	Pearly to vitr.	2.5–3	2.78–2.90	5	Mon.; us. scaly, gran.	C. basal, per.
	Apple-grn., gry., wh.	Greasy; C. pearly	1–2.5	2.55–2.80	5	Orth.(?); us. fol. or mass.	C. basal, per.
	Pink, gry., wh., yelh.	Vitreous; C. pearly	3.5–4.5	2.99–3.08	4–4.5	Mon.	C. basal, per.; brittle

			Name.	Compositio
FELD-SPARS: 2 cl. at 90° or nearly so; lt. col. Fus. dif. H. near 6 G. 2.5–2.8	K flame. w. powdered gypsum	Microcline may show striations on cl. or xl. faces, but us. not disting. by phys. or bp. characters	**ORTHOCLASE** (Potash Feldspar) T370 S315	$KAlSi_3O_8$ (Na iso. w. K)
			MICROCLINE T373 S322	$KAlSi_3O_8$ (Na iso. w. K)
	Strong Na flame w. powdered gypsum; little or no K	Us. fine striations on best cleav.; these *Plagioclase Feldspars* form a continuous series from albite to anorthite and are scarcely disting. by bp. methods. Labradorite slightly sol. in HCl; anorthite slowly sol. giving gel. sil.	**ALBITE** (Soda Feldspar) T377 S327	$NaAlSi_3O_8$ (Us. some Ca; o also)
			OLIGOCLASE (Na-Ca Feldspar) T378 S332	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($m : n = 6 : 1$ to 3
			ANDESINE (Na-Ca Feldspar) T379 S333	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($m : n = 3 : 2$ to 1
			LABRADORITE (Ca-Na Feldspar) T379 S334	$n(NaAlSi_3O_8)$ $m(CaAl_2Si_2O_8)$ ($m : n = 3 : 4$ to 1
			ANORTHITE (Lime Feldspar) T380 S337	$CaAl_2Si_2O_8$ (Us. also some N
Li flame (sometimes obscured by Na). (Cp. lepidolite)	Swells and fus. to clear or wh. glass. Hiddenite (emerald-green) and kunzite (lilac) are transp.		**SPODUMENE** (Hiddenite; Kunzite) T393 S366	$LiAl(SiO_3)_2$ (Na iso. w. Li)
	Blue phosphorescence with gentle heat. Fus. to wh. enamel		**Petalite** T369 S311	$LiAl(Si_2O_5)_2$ (Na iso. w. Li)
	F reac. w. glass and $KHSO_4$; P reac. after fus. w. soda		**Amblygonite** T503 S781	$Li(AlF)PO_4$ (Na iso. w. Li; O
B flame (Cp. axinite, below)	Rdh. phosphorescence on heating; fus. to cols. glass		**Danburite** T431 S490	$CaB_2(SiO_4)_2$
	Fus. w. intumes. to wh. globule; Cl reac. w. CuO on ch.		**Boracite** T518 S879	$Mg_7Cl_2B_{16}O_{30}$
	Much H_2O in c.t.		Howlite T519 S881	$Ca(BO.OH)_5Si$
B flame w. $KHSO_4$ and fluorite	Fus. w. intumes. and pale B flame		**Axinite** T441 S527	$Ca_7Al_4B_2(SiO_4)$ (Mn, Fe, Mg, Zn w. Ca)
	Fus. w. intumes. to blebby glass or slag. Pyroelectric, especially lighter colored varieties. Achroite cols.; indicolite blue; rubellite red		**TOURMALINE** (Schorl; Achroite; Indicolite; Rubellite) T447 S551	$R_{18}(BOH)_2(SiC$ (R = Al, Fe, Mg often some M Na, K, Li, H) (F iso. w. OH)

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Cols., wh., cream, flesh-red, gry., grn.	Vitreous to pearly	6	2.57	5	Mon.; Figs. 64–66	C. basal, per. and pinac. 90°
	Wh., cream, red, grn.	Vitr. to pearly	6–6.5	2.54–2.57	5	Tri.	C. basal, per and pinac. 89° 30′
K	Cols., wh., gry., redh., grn.	Vitreous to pearly	6–6.5	2.62–2.65	4–4.5	Tri.; Fig. 68	C. basal, per. and pinac. 86° 24′
:1)	Cols., wh., gry., grnh., bluish, redh. Often a beautiful play of colors on the pinacoid (010)	Vitr. to pearly	6–6.5	2.65–2.67	3.5–4	Tri.; us. mass.	C. basal, per. and pinac. 86° 32′
:)			5–6	2.68–2.69	3.5–4	Tri.; us. mass.	C. basal, per. and pinac. 86° 14′
:6)			5–6	2.70–2.73	3–3.5	Tri.; us. mass.	C. basal, per. and pinac. 86° 4′
	Cols., wh., gry., redh.	Vitr. to pearly	6–6.5	2.74–2.76	4.5–5	Tri.	C. basal, per. and pinac. 85° 50′
	Wh., gry., pink., emerald-grn., purple	Vitr. to pearly	6.5–7	3.13–3.20	3.5	Mon.; us. prism.	C. prism. per. F. uneven
	Wh., gry., pink, grnh.	Vitreous; C. pearly	6–6.5	2.39–2.46	4	Mon.; us. mass.	C. basal, per. F. uneven
w. F)	Wh. to pale grn., or blue	Vitr. to greasy; C. pearly	6	3.01–3.09	2	Tri.; us. mass.	C. basal, per. F. uneven
	Wh. to pale yel., yelh-brn. & cols.	Vitreous	7–7.25	2.97–3.02	3.5	Orth.	F. uneven
	Cols., wh., gry., yel., grn.	Vitreous	7	2.9–3.0	2	Iso. tetrh.; us. xls.	F. conch.
	Wh.	Vitreous	3.5	2.55–2.59	2	Nodular, fibrous	F. splint. or smooth
iso.	Clove-brn., gry., grn., yel., blk.	Vitreous	6.5–7	3.27–3.35	2–2.5	Tri. Fig. 67	C. pinac. F. conch.
fly; Ca,	Blk., brn., grn., blue, red, pink wh.	Vitreous to res.	7–7.5	2.98–3.20	3–5 Us. 3	Hex. rhom.; hemimor. Fig. 51	F. conch to uneven

			Name.	Compositior
Mn in soda bd.	Gel. w. HCl after fus.; iso.		**SPESSARTITE** (Mn Garnet) T417 S442	$Mn_3Al_2(SiO_4)_3$ (Us. also Fe and C
	Do not gel. after fus.; 2 cl. nearly 90°	Fus. to nearly blk. glass	**RHODONITE** T395 S378	$MnSiO_3$ (Fe, Ca iso. w. Mn
		Wh. ZnO subl. w. soda on ch. (slight); grn. w. $Co(NO_3)_2$	Fowlerite (Zn Rhodonite) T396 S378	$(Mn,Zn)SiO_3$ (Fe, Ca, Mg iso. w.
			Jeffersonite (Mn-Zn Pyroxene) T390 S358	(Ca,Mn)(Mg,Fe $(SiO_3)_2$
		Fus. to brnh. glass	Schefferite (Mn Pyroxene) T389 S357	(Ca,Mn)(Mg,Fe $(SiO_3)_2$
	Fus. w. much intumes. to blk. glass		**Piedmontite** (Mn Epidote) T440 S521	Ca_2(AlOH)(Al,M Fe)$(SiO_4)_3$
	C. perf. at 55° and 125° (Amphibole)		Richterite (Mn Amphibole) T401 S391	(Mg,Mn,Ca,Na_2 $(SiO_3)_4$
	Cb reac. after fus. w. borax; samarskite gives U reac. in s.ph. bd.		**COLUMBITE** T490 S731	$(Fe,Mn)Cb_2O_6$ (Also Ta, and some and W)
			Samarskite T492 S739	$R_3''R_2'''$(Nb,Ta)((R'' = Fe, Ca, UO_2) R''' = Ce and Y met
	W reac. after fus. w. soda	W. little soda on ch. becomes mag. (Cp. ferberite)	**WOLFRAMITE** T539 S982	$(Fe,Mn)WO_4$
		Yel. WO_3 res. on boiling in HCl. Scheelite reacts for Ca w. am. oxalate	**Hubnerite** T539 S982	$MnWO_4$ (Fe iso. w. Mn)
			Scheelite T540 S985	$CaWO_4$ (Us. also Mo; somet.
Ti in s.ph. bd.	Fus. w. slight intumes. to colored glass		**TITANITE** (Sphene) T485 S712	$CaTiSiO_5$ (Some Fe; somet. M
			Benitoite Ap. II, 14	$BaTi(SiO_3)_3$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
	Brnh-red to hyacinth-red	Vitreous	6.5–7.5	4.0–4.3	3	Iso.; us. xls.	F. uneven to conch.
	Rose-red, pink, brn.	Vitreous	5.5–6.5	3.4–3.68	2.5–3	Tri.; us. mass.	C. prism. per. F. uneven
n)	Rose-red	Vitreous	5.5–6.5	3.67	2.5–3	Tri.	C. prism. per. F. uneven
n)	Grnh-blk. to brn.	Vitreous	5–6	3.6	3–3.5	Mon.	C. prism. F. uneven
	Yelh-brn., redh-brn., blk.	Vitreous	5–6	3.5	4	Mon.	C. prism. F. uneven
.	Redh-brn. to redh-blk.	Vitreous	6.5	3.404	3	Mon.	C. basal, per. F. uneven
	Brn., yel., rose-red	Vitreous	5.5–6	3.09	4	Mon.; prism.	C. prism., per. F. uneven
n	Fe-blk. to gry. & brnh-blk.	Res. to submet.	6	5.3–6.5	5–5.5	Orth.; us. prism.	F. uneven
'21 s)	Velvet-blk.	Vitreous to res.	5–6	5.6–5.8	4.5–5	Orth.; us. mass.	F. conch.
	Dk. gryh-blk. to brnh. blk.	Res. to submet.	5–5.5	7.2–7.5	3–3.5	Mon.; us. xls.	C. pinac. per. F. uneven
	Brn. to brnh-blk.	Res.	5–5.5	6.89–7.35	4	Mon.	C. pinac. per. F. uneven
Cu)	Wh., yel., grn., brn., redh.	Vitr. to adamant	4.5–5	5.9–6.1	5	Tetr.	C. pyram. F. uneven
)	Gry., brn., yel., grn.	Res. to adamant	5–5.5	3.4–3.56	3	Mon.; us. xls.	C. prism. F. uneven
	Sapphire-blue, lt. blue, cols.		6.25–6.5	3.64–3.65	3	Hex.; us. prism.	

		Name.	Composition.
GARNET. — Fus. quietly (except uvarovite) and gel. w. HCl after fus. Us. dodecahedrons and trapezohedrons. (Figs. 13, 17, 18)	Ca (grossularite) or Mg (pyrope) ppt. after fus. w. soda and separating Si and Al. (See Silicon (2))	**GROSSULARITE** (Ca-Al Garnet) T416 S439	$Ca_3Al_2(SiO_4)_3$ (Fe, Mg, Mn iso. w. Fe iso. w. Al)
		PYROPE (Mg-Al Garnet) T416 S440	$Mg_3Al_2(SiO_4)_3$ (Fe, Ca iso. w. Mg; Fe, Cr, iso. w. Al)
	Fus. to mag. globule	**ALMANDITE** (Fe-Al Garnet) T416 S441	$Fe_3Al_2(SiO_4)_3$ (Mn, Mg, Ca iso. w.
	Mn in borax bd. (strong)	**SPESSARTITE** (Mn Garnet) T417 S442	$Mn_3Al_2(SiO_4)_3$ (Fe, Ca iso. w. Mn; Fe iso. w. Al)
	Partially sol. in HCl w. gel. sil.	**ANDRADITE** (Ca-Fe Garnet) T417 S437	$Ca_3Fe_2(SiO_4)_3$ (Fe, Mn, Mg, Ca iso Ca; Al iso. w. Fe)
	Cr in s.ph. bd.; fus. w. dif.	**Uvarovite** (Ca-Cr Garnet) T417 S444	$Ca_3Cr_2(SiO_4)_3$ (Al iso. w. Cr)
AMPHIBOLE Group.—Fus. quietly or w. little intumes. Prism and cl. angles 56° and 124°. Xls. us. prismatic, often divergent or radial-columnar. Separate xls. us. 6-sided, vertically striated, and terminated by 2 planes	Fus. to dark shiny globule; us. intumes. slightly and gives Na flame	**HORNBLENDE AMPHIBOLE** T402 S392	$Ca(Mg,Fe)_3(SiO_3)$ $Na_2(Al,Fe)_2(SiO$ $(Mg,Fe)_2(Al,Fe)$ $(SiO_6)_3$
	Fus. to grnh. or brnh. globule; but little Na flame	**ACTINOLITE** (Nephrite or Jade when compact) T400 S389	$Ca(Mg,Fe)_3(SiO_3)$
	Fus. to cols. or nearly cols. glass; sometimes asbestiform (fibrous)	**TREMOLITE** (Asbestos in part) T400 S388	$CaMg_3(SiO_3)_4$
	Dif. fus. (5–6); sometimes asbestiform	**Anthophyllite** (Asbestos in part) T398 S384	$(Mg,Fe)SiO_3$ (Somet. also Al)
	Strong Na flame (Cp. riebeckite)	**Glaucophane** T403 S399	$Na_2Al_2(SiO_3)_4$. $(Mg,Ce,Fe)_4(Si$
PYROXENE Group. —Fus. quietly or w. little intumes. Prism and cleav. angles 87° and 93°; cleav. not very pronounced. Xls. us. nearly square prism w. truncated edges. Basal parting often distinct	Dif. fus. (6); luster often metaloidal (Cp. hypersthene)	**ENSTATITE** (Bronzite) T384 S346	$(Mg,Fe)SiO_3$
	Fus. to cols. or nearly cols. glass	**DIOPSIDE** T388 S355	$CaMg(SiO_3)_2$ (Fe iso. w. Mg)
	Fus. to grnh. or brnh. glass; col. deepens w. increase of Fe. Diallage is lamellar to fibrous w. pearly to metalloidal luster (Continued next page)	**PYROXENE** (Diallage) T387 S356	$Ca(Mg,Fe)(SiO_3)_2$
		Hedenbergite T389 S352	$CaFe(SiO_3)_2$ (Mg iso. w. Fe)

	Color.	Luster.	Hard-ness.	Specific Gravity.	Fusi-bility.	Crystalliza-tion.	Cleavage and Fracture.
a;	Pale red, yel., grn., wh.	Vitreous	6.5–7.5	3.55–3.66	3	Iso.: us. xls.	F. uneven to conch
	Deep red to redh-blk., rarely purple	Vitreous	6.5–7.5	3.7–3.75	3.5–4	Iso.; us. xls.	F. uneven to conch.
'e)	Deep red to brnh-blk.	Vitreous	6.5–7.5	3.9–4.2	3	Iso.; us. xls.	F. uneven, conch.
	Brnh-red to hyacinth-red	Vitreous	6.5–7.5	4.0–4.3	3	Iso.; us. xls.	F. uneven to conch.
w.	Wine-red, grnh., yel., brn. to blk.	Vitr. to res.	6.5–7.5	3.8–3.9	3.5	Iso.; us. xls.	F. uneven to conch.
	Emerald-grn.	Vitreous	7.5	3.41–3.52	5.5–6	Iso.; us. xls.	F. conch.
.)₄.	Grn. to blk.	Vitr. to pearly	5–6	3.05–3.47	3–4	Mon.; us. xls.	C. prism. per. F. uneven
	Grn. of various shades	Vitr. to pearly	5–6	3.0–3.2	4	Mon.; prism.	C. prism. per. F. uneven
	Wh., gry.	Vitr. to pearly	5–6	2.9–3.1	4	Mon.	C. prism. per. F. uneven
	Gry., clove-brn., grn.	Vitr. to pearly	5.5–6	3.1–3.2	5–6	Orth.; us. fibr. or mass.	C. prism. per.
$)_3)_4$	Lavender-blue to azure-blue; gryh., and bluish-blk.	Vitr. to pearly	6–6.5	3.10–3.11	3–3.5	Mon.; us. mass.	C. prism. per. F. uneven
	Yelh., gry., brn., grn.	Pearly to bronzy	5.5	3.1–3.3	5–6	Orth.; us. mass.	C. prism. F. uneven
	Cols., wh., pale grn.	Vitreous	5–6	3.2–3.38	4	Mon.; us. xls.	C. prism. F. uneven
	Lt. to dk. grn.	Vitreous	5–6	3.1–3.5 Us. 3.3	4	Mon.; us. xls. Figs. 62, 63	C. prism. F. uneven
	Grnh-blk. to blk.	Vitreous	5–6	3.5–3.58	2.5–3	Mon.	C. prism. F. uneven

		Name.	Compositio
	Fus. to shiny blk. glass; often Na flame; contains Al and ferric Fe	**AUGITE** (Common Pyroxene of igneous rocks) T390 S358	$Ca(Mg,Fe)(SiO$ $(Mg,Fe)(Al,Fe)$ $Na(Al,Fe)(SiO_3$
	Fus. to blk. globule, somewhat mag.; strong Na flame	**Acmite** (Aegirite) T391 S364	$NaFe'''(SiO_3)_2$
	Fus. readily to transp. blebby glass; Na flame. Us. in very tough compact mass	**Jadeite** (Jade in part) T393 S369	$NaAl(SiO_3)_2$
Fus. easily to wh. transl. glass	Wh. ppt. $BaSO_4$ in HCl sol.; much H_2O in c.t. at low temp.	**Harmotome** T456 S581	$H_2(Ba,K_2)Al_2(Si$ $4H_2O$
Fus. easily to cols. blebby glass	Sol. w. gel. after ign.; H_2O in c.t.; very hard	Lawsonite T447 Ap. I, 41	$Ca[Al(OH)_2]_2(Si$
Fus. dif. and quietly (Cp. sericite, variety of muscovite)	Whitens and fus. to vesic. scoria; varieties with Na, Li, Cs, more fus.	**BERYL** (Emerald, deep grn.; Aquamarine, pale) T405 S405	$H_2Gl_6Al_4Si_{12}O_{37}$ (Na_2, Li_2, Cs_2 iso. w
	A little H_2O on intense ign. of powder in c.t.	**Iolite** (Cordierite) T407 S419	$H_2(Mg,Fe)_4$ $Al_8Si_{10}O_{37}$
Fus. to wh. enamel w. orange-yel. phosphorescence	Acid H_2O in c.t.; P reac. w. am. mol. after fus. w. soda	Herderite T503 S760	$Ca[Gl(F,OH)]P$
Fus. w. intumes.	To grnh. or brnh. glass; gel. w. HCl after fus.	**VESUVIANITE** (Idocrase) T427 S477	$Ca_6[Al(OH,F)]$ $(Al,Fe)_2(SiO$ (Mg, Fe, Mn iso. w
	To wh. blebby glass; strong Na flame; AgCl ppt. w. $AgNO_3$ in dil. HNO_3 sol. after fus. w. soda	**WERNERITE** (Scapolite) T425 S468	$n(Ca_4Al_6Si_6O_{25})$ $m(Na_4Al_3Si_9O_{24}C$ ($n : m = 3 : 1$ to 1 :
	To wh. blebby glass; gel. w. HCl after fus. H_2O in c.t.	**PREHNITE** T442 S530	$H_2Ca_2Al_2(SiO_4)_3$ (Fe iso. w. Al)
	To a slag which gel. w. HCl; a little H_2O on intense ign. of powder in c.t. — Lt. col. slag	**ZOISITE** T437 S513	$Ca_2(AlOH)Al_2(Si$
	To a slag which gel. w. HCl; a little H_2O on intense ign. of powder in c.t. — Brn. or blk. slag; us. mag.	**EPIDOTE** (Pistacite) T438 S516	$Ca_2(AlOH)(Al,F$ $(SiO_4)_3$
Exfoliates and fus. w. dif. Greasy feel	Pink col. after ign. w. $Co(NO_3)_2$; us. gives H_2O in c.t. on intense ign.	**TALC** (Steatite, Soapstone) T479 S678	$H_2Mg_3(SiO_3)_4$

	Color.	Luster.	Hardness.	Specific Gravity.	Fusibility.	Crystallization.	Cleavage and Fracture.
)a.	Grnh-blk. to blk.	Vitreous	5–6	3.26–3.43	3–4	Mon.	C. prism. F. uneven
	Grnh. to brnh-blk.	Vitreous	6–6.5	3.50–3.55	3.5	Mon.; prism.	C. prism. F. uneven
	Wh., gryh., grnh.	Vitreous C. pearly	6.5–7	3.33–3.35	2.5	Mon.; us. mass.	C. prism. F. splint.
s.	Wh., gry., yel., red, brn.	Vitreous	4.5	2.44–2.50	3.5	Mon.; us. twinned	C. pinac. F. uneven
s	Pale blue to gryh-blue	Vitr. to greasy	8.25	3.084–3.091	3	Orth.; us. xls.	C. basal and pinac., per.
l)	Grn., blue, yel., pink, cols.	Vitr. to res.	7.5–8	2.63–2.80 Us. 2.69–2.7	5–5.5	Hex.; us. xls.	F. conch. to uneven
	Blue to violet and cols.	Vitreous	7–7.5	2.60–2.66	5–5.5	Orth.	C. pinac. F. conch.
	Wh. to pale grn. or yel.	Vitreous	5	2.99–3.01	4–5	Mon.	F. uneven
a)	Grn., brn., yel., blue, red	Vitr. to res.	6.5	3.35–3.45	3	Tetr. Figs. 37, 38	F. uneven
	Wh., gry., grnh., bluish, redh.	Vitr. to pearly	5–6	2.66–2.73	3	Tetr.	C. prism. and pinac. F. uneven
	Apple-grn., gry., wh.	Vitreous	6.6–5	2.80–2.95	2	Orth.; us. reniform	F. uneven
)s	Gryh-wh., grn., pink, yelh-brn.	Vitreous; C. pearly	6–6.5	3.25–3.37	3–4	Orth.; us. prism.	C. pinac. per. F. uneven
	Yelh. to blkh-grn., gry.	Vitreous	6–7	3.25–3.5	3–4	Mon.; us. prism.	C. basal, per. F. uneven
	Apple-grn., gry., wh.	Greasy; C. pearly	1–2.5	2.55–2.80	5	Orth.(?); us. fol. or mass.	C. basal, per.

			Name.	Composition
CARBONATES.—CO_2 efferv. in dil. HCl	Sr flame; swells and throws out fine branches on intense ign.	Wh. ppt. $SrSO_4$ w. dil. H_2SO_4 in dil. HCl sol.	**STRONTIANITE** T362 S285	$SrCO_3$ (Somet. Ca iso w. Sr)
	Ba flame on intense ign.	Wh. ppt. $BaSO_4$ w. dil. H_2SO_4 in dil. HCl sol.	Barytocalcite T364 S289	$CaBa(CO_3)_2$
	Ca flame w. HCl; dil. H_2SO_4 gives wh. ppt. $CaSO_4$ in conc. HCl sol. but not in very dil. sol., showing presence of Ca and absence of Sr and Ba	Lumps efferv. freely in cold dil. HCl. Aragonite falls to powder below red heat in c.t.	**CALCITE** (Calc Spar; Marble; Limestone; Chalk.) T354 S262	$CaCO_3$ (Mg, Fe, Mn, Pb iso
			ARAGONITE T361 S281	$CaCO_3$ (Sr, Pb iso. w. Ca)
		Lumps efferv. freely in hot but not in cold dil. HCl; sol. reac. for Mg after ppt. of Ca	**DOLOMITE** (Pearl Spar) T357 S271	$CaMg(CO_3)_2$ (Fe, Mn, iso. w. Mg)
		Becomes blk. and slightly mag. on ign.; much $Fe(OH)_3$ ppt. w. am. after boiling HCl sol. w. a drop of HNO_3	**Ankerite** (Fe Dolomite) T358 S274	$Ca(Mg,Fe)(CO_3)_2$ (Mn iso. w. Mg)
		Much H_2O in c.t.; wh. $BaSO_4$ ppt. w. $BaCl_2$ in dil. HCl sol.	Thaumasite T483 S698	$CaCO_3.CaSiO_3.Ca$ $15H_2O$
	Contains Mg.—Little or no ppt. w. am. oxalate in HCl sol., but much w. Na phosphate Alkaline reac. w. turmeric paper may be weak	Scarcely affected by cold dil. HCl. Wh. fragments become pale pink on ign. w. $Co(NO_3)_2$. Breunnerite gives much $Fe(OH)_3$ ppt. w. am. after boiling HCl sol. w. a drop of HNO_3. Hydromagnesite gives much H_2O in c.t.	**MAGNESITE** T358 S274	$MgCO_3$ (Fe iso. w. Mg)
			Breunnerite (Fe Magnesite; Brown Spar) T358 S274	$(Mg,Fe)CO_3$ (Mn iso. w. Mg)
			Hydromagnesite T367 S304	$Mg_3(MgOH)_2(CO_3$
Sol. quietly in warm HCl	Glows on ign.; becomes pale pink if previously moistened w. $Co(NO_3)_2$		**BRUCITE** T351 S252	$Mg(OH)_2$ (Fe, Mn iso. w. Mg)
Sulphates.—Acid H_2O in c.t. and SO_2 odor after intense ign.	Al reac. w. $Co(NO_3)_2$	Readily sol. in H_2O	**Kalinite** (Potash Alum) T535 S951	$KAl(SO_4)_2.12H_2O$
		Slowly attacked by HCl	**Alunite** T537 S974	$K[Al(OH)_2]_3(SO_4)_2$ (Na iso. w. K)

	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Wh., gry., yel., grn.	Vitreous	3.5–4	3.68–3.71	Orth.; us. columnar	C. prism. F. uneven
	Wh., gry., yel., grn.	Vitreous	4	3.64–3.66	Mon.; us. prism.	C. prism. per. F. uneven
w. Ca)	Cols., wh., and variously tinted	Vitreous	3	2.71–2.72	Hex.; rhom. Figs. 45–50	C. rhom. per. F. conch.
	Cols., wh., and variously tinted	Vitreous	3.5–4	2.93–2.95	Orth.	C. pianc. poor F. uneven
	Cols., wh., and variously tinted	Vitr. to pearly	3.5–4	2.8–2.9	Hex. rhom.	C. rhom. per.
	Brn., gry., redh., seldom wh.	Vitr. to pearly	3.5–4	2.95–3.1	Hex. rhom.	C. rhom. per.
O_4.	Wh., cols.	Vitr. to dull	3.5	1.877	Hex.; fibr. or mass.	F. splint.
	Wh., yel., gry., brn.	Vitreous, silky, dull	3.5–4.5	3.0–3.12	Hex. rhom.; us. mass.	C. rhom. per.
	Yelh., brnh., gry. Seldom wh.	Vitreous	3.5–4.5	3.0–3.2	Hex. rhom.	C. rhom. per.
$.3H_2O$	Wh.	Vitr. to silky	3.5	2.15	Mon.; us. acic.	
	Wh., gry., grn., blue	Waxy, vitr. C. pearly	2.5	2.38–2.4	Hex. rhom.; us. tab.	C. basal, per.; flex.
	Cols., wh.	Vitreous	2–2.5	1.75	Iso. pyr.; us. fibr.	C. conch.
	Wh., gry., redh.	Vitreous	3.5–4	2.58–2.75	Hex. rhom.	C. basal F. uneven

			Name.	Compositio[n]
CARBONATES.—CO_2 efferv. in dil HCl.	Mn in borax bd.	Sometimes enough Fe to make mag. on ch.	**RHODOCHROSITE** (Dialogite) T359 S278	$MnCO_3$ (Ca, Fe, Mg, Zn iso.
	Ni in borax bd.	H_2O in c.t.	**Zaratite** T367 S306	$(NiOH)_2CO_3.Ni(O$ $4H_2O$
	Wh. ZnO subl. w. soda on ch. Grn. subl. if ch. previously moistened w. $Co(NO_3)_2$	Little or no H_2O in c.t.	**SMITHSONITE** (Dry-bone Ore; Calamine) T360 S279	$ZnCO_3$ (Ca, Mg, Fe, Mn, Co
		H_2O in c.t.; Cu flame w. HCl	**Aurichalcite** T366 S298	$2(Zn,Cu)CO_3.3(Zn$ $(OH)_2$
		H_2O in c.t.; no Cu	Hydrozincite T366 S299	$ZnCO_3.2Zn(OH)_2$
	Become blk. and mag. on ign.; ferrous Fe	HCl sol. reac. for both Mg and Fe. (See breunnerite, Sec. 24)	**Breunnerite** (Fe Magnesite; Brown Spar) T358 S274	$(Mg,Fe)CO_3$ (Mn iso. w. Mg)
		Little or no Mg or Ca. (See Magnesium (3))	**SIDERITE** (Spathic Iron) T359 S276	$FeCO_3$ (Ca, Mg, Mn iso. w.
	Mg reac. in HCl. sol. after removing Fe and Ca. (See Magnesium (3))	Little or no H_2O in c.t.	**MAGNESITE** T358 S274	$Mg\ CO_3$ (Fe iso. w. Mg)
		Much H_2O in c.t.	Hydromagnesite T367 S304	$Mg_2(MgOH)_2(CO$
SULPHIDES.—H_2S efferv. in hot HCl	Wh. ZnO subl. after intense ign. w. soda on ch.; subl. grn. w. $Co(NO_3)_2$		**SPHALERITE** (Zinc Blende) T291 S59	ZnS (Fe, Mn, Cd iso. w. Z
	Red-brn. CdO subl. after intense ign. w. soda on ch.		**Greenockite** T294 S69	CdS
SULPHATES.—Wh. ppt. $BaSO_4$ w. $BaCl_2$ in HCl sol.	Al reac. w. $Co(NO_3)_2$ on ch.	Readily sol. in H_2O; K flame	**Kalinite** (Potash Alum) T535 S951	$KAl(SO_4)_2.12H_2O$
		Sol. in H_2O; no flame reac.	Alunogen T535 S958	$Al_2(SO_4)_3.18H_2O$
		Insol. in H_2O	Aluminite T537 S970	$Al_2(OH)_4SO_4.7H_2($
	Readily sol. in H_2O; wh. ZnO subl. w. soda on ch. after intense ign.		Goslarite T533 S939	$ZnSO_4.7H_2O$ (Fe iso. w. Zn)

ι.	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystalliza-tion.	Cleavage and Fracture.
w. Mn)	Rose-red, dk. red, brn.	Vitr. to pearly	3.5–4.5	3.45–3.60	Hex. rhom.; us. mass.	C. rhom. per. F. uneven
'H)₂.	Emerald-grn.	Vitreous	3–3.25	2.6–2.7	Mass.; compact	F. smooth
iso. w. Zn)	Brn., grn., blue, pink, wh.	Vitreous	5	4.30–4.45	Hex. rhom.; us. botry.	C. rhom. per. F. uneven
ι,Cu)	Pale grn. to blue	Pearly	2	3.54–3.64	Mon.; us. acic.	
	Wh., gry., yel.	Dull	2–2.5	3.58–3.8	Earthy; compact	
	Yelh. brnh., gry. Seldom wh.	Vitreous	3.5–4.5	3.0–3.2	Hex. rhom.	C. rhom. per.
'e)	Gry. & brn. of different shades	Vitr. to pearly	3.5–4	3.83–3.88	Hex. rhom.	C. rhom. per. F. uneven
	Wh., yel., gry., brn.	Vitreous, silky, dull	3.5–4.5	3.0–3.12	Hex. rhom.; us. mass.	C. rhom. per.
)₂.3H₂O	Wh.	Vitreous to silky	3.5	2.15	Mon.; us. acic.	
ı)	Wh., grn., yel., red, brn., blk.	Res. to adamant	3.5–4	3.9–4.1	Iso. tetr.; us. mass.	C. dodec. per. F. conch.
	Honey, citron, or orange-yel.	Res. to adamant	3.0–3.5	4.9–5.0	Hex. hemimor.; us. incrust.	C. prism. F. conch.
	Cols., wh.	Vitreous	2–2.5	1.75	Iso. pyr.; us. fibr.	C. conch.
	Wh., yelh., redh.	Vitr. to silky	1.5–2	1.6–1.8	Mon.; us. fibr.	
	Wh., opaq.	Dull, earthy	1–2	1.66	Mon.; us. compact, reniform	F. earthy
	Wh., yelh., redh.	Vitreous	2–2.5	1.9–2.1	Orth.; us. mass.	C. pinac. per.

			Name.	Compositio
Contains Fe; blackens and becomes strongly mag. b.b.; fus. (5–6) in fine splinters; slowly sol. in HCl to yel. sol. which reacts for ferric Fe	St. brnh-red	Little or no H_2O in c.t.	**HEMATITE** T334 S213	Fe_2O_3
		H_2O in c.t.; us. decrepitates	**Turgite** (Hydrohematite) T350 S245	$(FeO.OH)_2Fe_2O_3$
	St. yelh-brn. H_2O in c.t.	Us. prismatic xls.	**GOETHITE** (Göthite) T349 S247	$FeO(OH)$
		Amorphous, mammillary, botryoidal, stalactitic	**LIMONITE** (Brown Hematite; Bog Iron Ore) T350 S250	$Fe_2(OH)_6Fe_2O_3$
Mn in borax bd.	Wh. ZnO subl. w. soda on ch. after intense ign.; subl. grn. w. $Co(NO_3)_2$		**ZINCITE** (Red Zinc Ore) T332 S208	ZnO (Mn iso. w. Zn)
	Earthy, powdery, frothy; H_2O in c.t.		**WAD** (Bog Manganese) T352 S257	MnO,MnO_2,H_2O (Often Fe, Si, Al, B
Co in borax bd.	Mn in soda bd.; H_2O in c.t.		Asbolite (Earthy Cobalt) T352 S258	Co,Mn oxides (Often Fe, Si, Al)
P reac. w. am. mol.	Wh. $CaSO_4$ ppt. w. H_2SO_4 in cold conc. HCl sol. F reac. w. H_2SO_4		**APATITE** T497 S762	$Ca_4(CaF)(PO_4)_3$ (Cl iso. w. F. Ra
Much Mg; no Ca (See Magnesium (3))	Brilliant glow on intense ign.; Mg reac. w. $Co(NO_3)_2$ on ch. if mineral is lt. col.		**BRUCITE** T351 S252	$Mg(OH)_2$ (Fe, Mn iso. w. Mg

SECT

Wh. ZnO subl. w. soda on ch. Grn. subl. if ch. previously moistened w. $Co(NO_3)_2$.	H_2O in c.t.; pyroelectric		**CALAMINE** (Hemimorphite; Smithsonite) T446 S546	$(ZnOH)_2SiO_3$
	Little or no H_2O in c.t.	A little H_2S on sol. in HCl	Danalite T414 S435	$Gl_3R_3(RS)(SiO_4$ (R = Mn, Fe, Zn)
		No H_2S on sol. in HCl (Cp. troostite)	**WILLEMITE** T422 S460	Zn_2SiO_4 (Mn, Fe iso. w. Z
Cu globule w. soda on ch.	H_2O in c.t.		**Dioptase** T424 S463	H_2CuSiO_4

	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystalliza-tion.	Cleavage and Fracture.
	Red to redh-blk.	Dull to submet.	5.5–6.5	4.9–5.3	Mass.; earthy	F. uneven, splint.
	Red to redh-blk.	Dull to submet.	5.5–6	4.14–4.6	Botry.; crusts	F. uneven, splint.
	Yel. or redh-brn. to blk.	Dull to adamant.	5–5.5	4–4.4	Orth.; us. prism.	C. pinac. per. F. splint.
	Yel., brn. to brnh. blk.	Dull, silky	5–5.5	3.6–4	Mass.; fibr.	F. splint
	Deep red to orange-yel. St. yel.	Adamant.	4–4.5	5.43–5.7	Hex. hemimor.; us. mass.	C. basal, per. F. uneven
	Bluish or brnh-blk. to dull blk.	Dull	1–6	3–4.26	Earthy; mass.	F. uneven
	Blk., brn.	Dull	1–2.5	3.15–3.29	Mass.; earthy	
r Mn)	Grn., blue, violet, brn., yelh., cols.	Vitr. to subres.	4.5–5	3.17–3.23	Hex.	C. basal F. uneven
	Wh., gry., grn., blue	Waxy, vitr.; C. pearly	2.5	2.38–2.4	Hex. rhom.; us. tab.	C. basal, per.; flex.

N 26.

	Wh., pale-grn., blue	Vitreous	4.5–5	3.4–3.5	Orth. hemimor.	C. prism. per. F. uneven
	Flesh-red to gry.	Vitr. to res.	5.5–6	3.427	Iso tetrh.; us. mass.	F. uneven
	Yel., red, grn., brn., wh., cols.	Vitreous	5.5	3.9–4.18	Hex. rhom.	C. basal and prism. F. uneven
	Emerald-grn.	Vitreous	5	3.28–3.35	Hex. rhom.; us. prism.	C. rhom. per. F. conch.

		Name.	Compositio
Fe in borax bd.; little or no H_2O in c.t. (Cp. the next 3 minerals, which often react for Fe)	Much Mg but no Al or Ca in HCl sol. (See Magnesium (3))	**CHRYSOLITE** (Olivine, Peridot) T420 S451	$(Mg,Fe)_2SiO_4$
	Swells and cracks apart on ign.; often glows	**Gadolinite** T436 S509	$Gl_2Fe(YO)_2(SiO_4)_2$
F reac. w. $KHSO_4$ and glass in c.t.; may also react for Fe	A little H_2O on intense ign. in c.t.; disting. by xln. or by quantitative chemical analysis	**Chondrodite** T443 S536	$Mg_3[Mg(F,OH)]_2($
		Humite T443 S 535	$Mg_5[Mg(F,OH)]_2($
		Clinohumite T443 S538	$Mg_7[Mg(F,OH)]_2($
Al reac. w. $Co(NO_3)_2$ on ch.	Much H_2O in c.t.; crumbles on ign.	**Allophane** T483 S693	$Al_2SiO_5.5H_2O$

SECTI

Cu globule w. soda on ch.	Darkens and gives H_2O in c.t.	**Chrysocolla** T483 S699	$CuSiO_3.2H_2O$
Ni in borax bd.	Darkens and gives H_2O in c.t.	**Garnierite** (Genthite) T479 S676	$H_2(Ni,Mg)SiO_4.n$
Blackens and becomes mag. b.b.	H_2O in c.t.; ferric Fe in HCl sol.	Chloropal T484 S701	$H_6Fe_2(SiO_4)_3.2H_2$
H_2O in c.t.; amorphous, fibrous, or foliated	Us. compact grnh.; sometimes fibrous (chrysotile, commercial "asbestos") or foliated (marmolite)	**SERPENTINE** (Chrysotile; Marmolite) T476 S669	$H_4(Mg,Fe)_3Si_2O_9$ (Somet. Ni, iso. w. M
	Resembles a gum or resin	**Deweylite** (Gymnite) T479 S676	$H_4Mg_4(SiO_4)_3.2H$ (Somet. Ni iso. w. M
	Compact; fine earthy texture; Mg reac. w. $Co(NO_3)_2$ on ch. Fus. = 5. Adheres to tongue	Sepiolite (Meerschaum) T480 S680	$H_4Mg_2Si_3O_{10}$ (Somet. Cu and Ni is
Al reac. w. $Co(NO_3)_2$ on ch.	K flame w. powdered gypsum; us. trapezohedrons	**LEUCITE** T381 S342	$KAl(SiO_3)_2$ (Na iso. w. K)
	Clay-like; sometimes transl. or transp. in H_2O	Halloysite T481 S688	$H_4Al_2Si_2O_9.nH_2O$

n.	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Olive-grn. to gryh-grn., brn.	Vitreous	6.5–7	3.27–3.37	Orth. Fig. 58	C. pinac. F. conch.
	Blk., grnh.-blk., brn.	Vitr. to greasy	6.5–7	4.0–4.5	Mon.; us. mass.	F. conch., splint.
$SiO_4)_2$	Brnh-red., yel., wh.	Vitreous	6–6.5	3.1–3.2	Mon.	C. basal F. uneven
$SiO_4)_3$	Brnh-red, yel., wh.	Vitreous	6–6.5	3.1–3.2	Orth.	C. basal F. uneven
$SiO_4)_4$	Brnh-red., yel., wh.	Vitreous	6–6.5	3.1–3.2	Mon.	C. basal F. uneven
	Cols., yel., grn., blue	Vitr. to waxy	3	1.85–1.89	Amorph.; us. crusts	F. conch.

ON 27.

	Bluish-grn., grnh-blue, brn., blk.	Vitreous, earthy	2–4	2.0–2.24	Mass.; earthy	F. conch. to uneven
H_2O	Pale to deep grn., yelh.	Dull to res.	1–4	2.2–2.8	Amorph.; botry.	F. uneven
)	Grnh. yel., pistachio-grn.	Waxy	2.5–4.5	1.73–1.87	Compact; amorph.	F. conch., splint., earthy
g)	Olive-grn., blkh-grn., yelh-grn., wh.	Greasy, waxy, silky	2.5–5 Us. 4	2.5–2.65	Mass.; pseudm.	F. uneven, splint.
O g)	Yelh-brn., wh., apple-grn.	Res.	2–3.5	2.0–2.2	Amorph.	F. uneven, conch.
o. w. Mg)	Wh., to gryh-wh.	Dull	2–2.5	2.0	Compact; earthy	F. uneven
	Wh., gry., cols.	Vitreous	5.5–6	2.45–2.50	Iso.; us. xls.	F. uneven, conch.
	Wh., gry., grnh., yelh., bluish, redh.	Pearly, waxy, dull	1–2	2.0–2.2	Mass.; earthy	

			Name.	Compositio
Wh. ZnO subl. w. soda on ch.; grn. w. $Co(NO_3)_2$		Slowly attacked by hot HCl w. evolution of H_2S	**SPHALERITE** (Zinc Blende) T291 S59	ZnS (Fe, Mn, Cd iso. w.
Become strongly mag. on ign.		Slowly and dif. sol. in HCl	**IRON ORES** See Section 13	
Micaceous or foliated	Foliæ tough and elastic	Fus. w. dif.	**MICAS** See Section 23	-
	Foliæ flexible but not elastic (Cp. talc, below)	Much H_2O in c.t. on intense ign.; varieties rich in Fe become black and mag. (prochlorite)	**CHLORITE** (Clinochlore; Penninite: Prochlorite) T472 S643	$H_8(Mg,Fe)_5Al_2Si_3$ (Often a little Cr)
		Cr in borax bd.; rdh. col.	Kämmererite (Chrome Chlorite) T474 S650	$H_8(Mg,Fe)_5(Al,C$
	Foliæ brittle (brittle micas) H_2O in c.t.	Whitens and fus. w. dif. on thin edges	**Margarite** (Brittle Mica) T470 S636	$H_2CaAl_4Si_2O_{12}$
		Whitens b.b., but infus.	**Seybertite** (Clintonite) T471 S638	$H_3(Mg,Ca)_5Al_5Si_2$
Greasy feel; very soft	A little H_2O in c.t. on intense ign. (Cp. kaolinite and bauxite, below)	Al reac. w. $Co(NO_3)_2$ on ch.; radiated variety exfoliates greatly b.b.	**PYROPHYLLITE** (Agalmatolite) T482 S691	$H_2Al_2(SiO_3)_4$
		Mg reac. w. $Co(NO_3)_2$ on ch.	**TALC** (Steatite; Soapstone) T479 S678	$H_2Mg_3(SiO_3)_4$
	Much H_2O readily given in c.t.	Like butter or cheese; brittle when dry; decomposed by H_2SO_4	Saponite T480 S682	$Mg_4Al(OH)_3(SiO_3$
P reac. w. am. mol. after fus. w. soda; us. pale blue-grn. flame		Monazite us. transp. or transl.; Xenotime is opaq.	**MONAZITE** T495 S749	(Ce,La,Nd,Pr)PO (Often w. $ThSiO_4$)
			Xenotime T494 S748	YPO_4 (Er; somet. Ce and
		Al reac. w. $Co(NO_3)_2$ on ch.; wavellite us. radiated or globular; variscite sheaf-like and reniform	**Wavellite** T512 S842	$(AlOH)_6(PO_4)_4.9H$ (F iso. w. OH)
			Variscite T510 S824	$AlPO_4.2H_2O$
		Blue col.; b.b. swells, loses col. and crumbles	**Lazulite** T506 S798	$(Mg,Fe)(AlOH)_2($

1.	Color.	Luster.	Hardness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
n)	Wh.,grn., yel., red, brn., blk.	Res. to adamant	3.5–4	3.9–4.1	Iso. tetrh.; us. mass.	C. dodec. per. F. conch.
$)_{18}$	Grn. of various shades	Vitr. to pearly	1–2.5	2.6–2.96	Mon.	C. basal, per.
$)_2Si_3O_{18}$	Rose-red to deep red	Vitr. to pearly	2–2.5	2.65–3.1	Mon.	C. basal, per.
	Pink, gry., wh., yelh.	Vitreous; C. pearly	3.5–4.5	2.99–3.08	Mon.	C. basal, per.; brittle
$)_{18}$	Redh-brn., Cu-red, yelh.	Pearly to submet.	4–5	3.0–3.1	Mon.	C. basal, per. F. uneven
	Wh., apple-grn., gry., yel., brn.	Pearly to dull	1–2	2.8–2.9	Fol., fibr., mass.	C. basal, per.; flexible
	Apple-grn., gry., wh.	Greasy; C. pearly	1–2.5	2.55–2.80	Orth.(?); us. fol. or mass.	C. basal, per.
$_5 . 14H_2O$	Wh., yelh., grnh., bluish, redh.	Greasy		2.24–2.30	Amorph.; mass.	
	Yelh-grn. to yelh- and redh-brn.	Res.	5–5.5	4.9–5.3	Mon.	P. (?) basal F. uneven
h)	Yelh. to redh-brn.	Res. to vitr.	4–5	4.45–4.56	Tetr.	C. prism. per. F. uneven
$_2O$	Wh., yel., grn., brn.	Vitr. to pearly	3–4	2.32–2.34	Orth.; us. radial	C. pinac. F. uneven
	Cols., apple-grn. to emerald-grn.	Vitreous	4	2.4	Orth.; us. mass.	
$O_4)_2$	Azure-blue	Vitreous	5–6	3.05–3.12	Mon.	C. prism. F. uneven

			Name.	Compositi
Al reac. w. $Co(NO_3)_2$ on ch.	Little or no H_2O in c.t.		**CYANITE** (Disthene) T434 S500	$(AlO)_2SiO_3$
	H_2O in c.t.	SO_2 fumes and acid H_2O w. intense heat in c.t.	**Alunite** T537 S974	$K[Al(OH)_2]_3(SO_4$ (Na iso. w. K)
		Insol. sil. skeleton in s.ph.bd.; us. clay-like, compact, or mealy	**KAOLINITE** (Kaolin; Porcelain Clay) T481 S685	$H_4Al_2Si_2O_9$
		Wholly sol. in s.ph. bd. Gibbsite us. incrust. or stalactitic; bauxite pisolitic and clay-like	**BAUXITE** (Aluminum Ore) T350 S251	$Al_2O(OH)_4$ (Often Fe, Si, Ca,
			Gibbsite (Hydrargillite) T351 S254	$Al(OH)_3$
Ni in borax bd.	Blackens and gives H_2O in c.t.		**Garnierite** (Genthite) T479 S676	$H_2(Ni,Mg)SiO_4$.
W in s.ph. bd.; yel. WO_3 res. in boiling HCl	Ca reac. w. am. oxalate in HCl sol.		**Scheelite** T540 S985	$CaWO_4$ (Us. also Mo; som
Ti in s.ph. bd.	Violet col. (Ti) appears before the blue (Cb) when HCl sol. of Pyrochlore is boiled with Sn		**Perovskite** (Perofskite) T487 S722	$CaTiO_3$ (Fe iso. w. Ca)
			Pyrochlore T489 S726	$RCb_2O_6.R(Ti,T$ (R = Ce, Ca, Na, present)
Cb reac. after fus. w. borax	Turns yel. and gives H_2O in c.t.		Yttrotantalite T492 S738	(Ca,Fe)(Y,Er)(.$4H_2O$ (Also us. Ce, U, a
	Slight reac. for Cb		Microlite T489 S728	$Ca_2Ta_2O_7$ (Us. also Cb, Na,

SECT

Become mag. on ign.	Slowly and dif. sol. in HCl	**IRON ORES** See Section 13	
	Cr in s.ph. bd. (Cp. picotite)	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; Al and Fe''' iso. w
(Continued next page)	Cleav. and prism angles 88° and 92°; often has a metalloidal luster	**Hypersthene** T385 S348	$(Mg,Fe)_2SiO_3$

l.	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Blue, grn., gry., wh.	Vitr. to pearly	5–7.25	3.56–3.67	Tri.; us. bladed	C. pinac. per. P. basal F. Splint
	Wh., gryh., redh.	Vitreous	3.5–4	2.58–2.75	Hex. rhom.	C. basal F. uneven
	Wh., yelh., redh., brnh.	Pearly, dull	1–2.5	2.6–2.63	Mon.; us. clay-like	C. basal, per. F. earthy
:)	Wh., gry., yel., red	Dull, earthy	1–3	2.55	Mass; clay-like	Oolitic; earthy
	Wh., gryh., grnh., redh.	Vitr., dull C. pearly	2.5–3.5	2.3–2.4	Mon.	C. basal, per.; tough
H_2O	Pale to deep grn., yelh.	Dull to res.	1–4	2.2–2.8	Amorph.; botry.	F. uneven
Cu)	Wh., yel., grn., brn., redh.	Vitr. to adamant.	4.5–5	5.9–6.1	Tetr.	C. pyram. F. uneven
	Yel. & brn. to blk.	Adamant. to sub-met.	5.5	4.017–4.039	Iso.	C. cubic F. uneven
O_3 F us.	Brn. to redh. and brnh-blk.	Vitr. to res.	5–5.5	4.2–4.36	Iso.; us. oct.	C. oct. F. conch.
,Cb)$_4$O$_{15}$ W)	Yel. to brn. and blk.	Vitr. to submet.	5–5.5	5.5–5.9	Orth.; us. prism.	F. conch.
, F, H)	Pale yel. to brn.	Res.	5.5	5.48–5.56 (From Va., 6.13)	Iso.; us. oct.	F. conch.

ON 29.

r)	Fe-blk. to brnh-blk.	Dull to submet.	5.5	4.32–4.57	Iso.; us. mass.	F. uneven
	Grnh-blk. to brn. & bronze	Pearly to bronzy	5–6	3.4–3.5	Orth.; us. mass.	C. pinac. per. F. uneven

			Name.	Compositic
	Cleav. and prism angles 54° and 126°; us. slender prisms, often fibrous (asbestos)		**Anthophyllite** (Asbestos in part) T398 S384	(Mg,Fe)SiO_3 (Somet. also Al)
	H_2O in c.t. on intense ign.	Rosettes; foliated; thin scales	Chloritoid T472 S640	H_2(Fe,Mg)Al_2SiO
		Oblong shining scales and plates	Ottrelite T471 S642	H_2(Fe,Mn)(Al,Fe
Blackens b.b. but does not become mag.	Cleav. and prism angles 88° and 92°; often has bronzy, metalloidal luster. (Cp. turquois, which darkens; also the preceding minerals of this section, which do not always become mag.)		**ENSTSATITE** (Bronzite) T 384 S346	(Mg,Fe)SiO_3
Whitens b.b. and fus. slightly on intense ign.	B flame w. $KHSO_4$ and CaF_2 (fluorite) on Pt wire; pyroelectric. Achroite cols., indicolite blue, rubellite red		**TOURMALINE** (Schorl; Achroite; Indicolite; Rubellite) T447 S551	$R_{15}(BOH)_2(SiO_5)_4$ (R = Al, Fe, Mg ch some Mn, Ca, Na (F iso. w. OH)
	Whitens at red heat; gives a little H_2O in c.t. on intense ign. (Cp. the next 8 minerals, which also give H_2O)		**BERYL** (Emerald, bright grn.; Aquamarine, pale) T405 S405	$H_2Gl_6Al_4Si_{12}O_{37}$ (Na$_2$, Li$_2$, Cs$_2$ iso. w
H_2O in c.t. on intense ign. if not before. (Cp. beryl, above)	Cu flame; P reac. w. am. mol. after fus. w. soda		**Turquois** T512 S844	H[Al(OH)$_2$]$_2$PO$_4$ (CuOH iso. w. Al(O
	Al reac. w. Co$(NO_3)_2$ on ch.		**Diaspore** T348 S246	AlO(OH)
	A little H_2O on intense ign. in c.t. Staurolite prismatic and often twinned. (Cp. polycrase, below, which gives a little H_2O)		**Iolite** (Cordierite) T407 S419	H_2(Mg,Fe)$_4$Al$_8$Si
			STAUROLITE T450 S558	(AlO)$_4$(AlOH)Fe (Fe iso. w. Al; Mg
	Fus. w. equal amt. of soda on Pt wire to clear glass. Hyalite is cols. and transp.		**OPAL** (Hyalite) T329 S194	$SiO_2 . nH_2O$
	May become mag. Chloritoid us. foliated or hex. plates and scales; ottrelite oblong shining scales and plates		Chloritoid T471 S640	H_2(Fe,Mg)Al_2Si(
			Ottrelite T472 S642	H_2(Fe,Mn)(Al,F
	Turns yel. in c.t.; Cb reac. after fus. w. borax		Yttrotantalite T492 S738	(Ca,Fe)(Y,Er)(T 4H_2O (Also us. Ce, U, an

	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystalliza-tion.	Cleavage and Fracture.
	Gry., clove-brn., grn.	Vitreous; C. pearly	5.5–6	3.1–3.2	Orth.; us. fibr. or mass.	C. prism. per.
	Dk. gry., grn., grnh-blk.	Pearly	6.5	3.52–3.57	Tri.(?); us. fol.	C. basal, per.; brittle
Si_2O_9	Grnh-gry., blk.	Vitreous	6–7	3.26–3.3	Tri.(?)	C. basal, per.
	Yelh., gry., brn., grn.	Pearly to bronzy	5.5	3.1–3.3	Orth.; us. mass.	C. prism. F. uneven
ly; often K, Li, H)	Brn., grn., blue, red, pink, wh., cols.	Vitreous	7–7.5	2.98–3.20	Hex. rhom.; hemimorph. Fig. 51	F. conch to uneven
l)	Grn., blue, yel., pink, cols.	Vitr. to res.	7.5–8	2.63–2.80 Us. 2.69–2.70	Hex.; us. xls.	F. conch to uneven
2)	Blue, bluish-grn., grn.	Waxy	6	2.6–2.8	Tri.; us. mass.	F. uneven to conch.
	Wh.,gry.,yelh., grnh., brn.	Pearly to vitreous	6.5–7	3.3–3.5	Orth.	C. pianc. per. F. conch.
$_{37}$	Lt. to dk. blue; rarely cols.	Vitreous	7–7.5	2.60–2.66	Orth.	C. pinac. F. conch.
$O_4)_2$ Fe)	Yelh-brn., redh-brn. to brnh-blk.	Res. to vitreous	7–7.5	3.65–3.77	Orth. Figs. 53–55	C. pinac. F. uneven
	Cols., red, yel., grn., blue, gry.	Vitr. to res.	5.5–6.5	1.9–2.3	Amorph.	F. conch.
	Dk. gry., grn., grnh-blk.	Pearly	6.5	3.52–3.57	Tri.(?); us. fol.	C. basal, per.; brittle
Si_2O_9	Grnh-gry., blk.	Vitreous	6–7	3.26–3.3	Tri.(?)	C. basal, per.
$Cb)_4O_{15}$. V)	Yel. to brn. and blk.	Vitr. to submet.	5–5.5	5.5–5.9	Orth.; us. prism.	F. conch.

		Name.	Compositi
Cb reac. after fus. w. borax	Us. Mn reac. in soda bd.	**COLUMBITE** T490 S731	$(Fe,Mn)Cb_2O_6$ (Also Ta and some
	Disting. by st. and dull exterior	**Fergusonite** T490 S729	$Y(Cb,Ta)O_4$ (Er, Ce, U iso. w. Y)
	Glows on ign. and becomes lighter col.; decrepitates and gives trace of H_2O in c.t.	Polycrase T493 S744	Uncertain: Cb, T Ce, Fe, H, O
Little or no Cb; Mn in soda bd.	Fe in s.ph. bd.; very heavy (G. above 6)	Tantalite T490 S731	$(Fe,Mn)Ta_2O_6$ (Cb iso. w. Ta; sligh
Ti in s.ph. w. Sn on ch.	Xls. us. prismatic, often very slender and twinned	**RUTILE** T345 S237	TiO_2 (Us. a little Fe)
	Xls. us. pyramids	**Octahedrite** (Anatase) T346 S240	TiO_2
	Xls. often tabular	**Brookite** T347 S242	TiO_2
Sn globule w. soda and ch. powder on ch.	Wh. subl. SnO_2 on intense ign. w. soda on ch.	**CASSITERITE** (Tin Stone) T344 S234	SnO_2
Zr reac. w. HCl and turmeric paper after fus. w. soda	Glows w. wh. light on intense ign. Hyacinth is transp. red or brown	**ZIRCON** (Hyacinth) T429 S482	$ZrSiO_4$ (Us. a little Fe)
Fus. w. equal amt. of soda on Pt wire to clear glass. (Cp. opal, p. 128)	Xls. us. hex. prisms; agate, jasper, chert, flint, and chalcedony are dense, compact varieties; amethyst, purple	**QUARTZ** (Amethyst; Agate; Jasper; Chalcedony; Chert; Flint) T324 S183	SiO_2
	Xls. us. thin hex. plates	**Tridymite** T328 S192	SiO_2
Wh. enamel w. soda; slowly sol. in borax to clear glass	Dull blue w. $Co(NO_3)_2$ on ch.	**Phenacite** T423 S462	Gl_2SiO_4
Al reac. w. $Co(NO_3)_2$ on ch.	F reac. w. $NaPO_3$ (powdered s.ph. beads) in c.t.	**TOPAZ** T431—S492	$Al(F,OH)_2AlSiO_4$
	Xls. us. stout rectangular	**ANDALUSITE** (Chiastolite) T432 S496	$(AlO)AlSiO_4$
(Continued next page)	Us. fibrous or slender xls.	**SILLIMANITE** (Fibrolite) T433 S498	Al_2SiO_5

	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
nd W)	Fe-blk. to gry. and brnh-blk.	Res. to submet.	6	5.3–6.5	Orth.; us. prism.	F. uneven
	Brnh-blk.	Pale brn.	5.5–6	4.3–5.8	Tetr.; us. mass.	F. uneven
Y, Er,	Brnh-blk. to blk.	Vitr. to res.	5–6	4.97–5.04	Orth.; us. prism.	F. conch.
n & W)	Blk.	Res. to submet.	6	6.5–7.3	Orth.	
	Redh-brn. to blk. & yelh.	Adamant., submet.	6–6.5	4.18–4.25	Tetr.; us. xls.	C. prism. F. uneven
	Brn. to dk-blue and blk.	Adamant., submet.	5.5–6	3.82–3.95	Tetr.; us. pyram.	C. basal and pyram. F. conch.
	Hair-brn. to blk.	Adamant., submet.	5.5–6	3.87–4.08	Orth.; us. xls.	F. uneven
	Brn. to blk.; rarely yel., red., gry., wh.	Adamant.	6–7	6.8–7.1	Tetr. Fig. 39	F. uneven
	Cols., gry., grn., brn., red	Adamant.	7.5	4.2–4.86 Us. 4.68–4.70	Tetr.; us. xls.	C. prism. F. conch.
	Cols., wh., yel., red, grn., blue, brn., blk.	Vitr. to greasy	7	2.60–2.66 Xls. 2.66	Hex. rhom.	F. conch.
	Cols., wh.	Vitreous	7	2.28–2.33	Hex.; tabular	F. conch.
	Cols., wh., yel., rose, brn.	Vitreous	7.5–8	2.97–3.0	Hex. rhom.; us. xls.	C. prism. F. conch.
	Cols., wh., yel., pink, bluish, grnh.	Vitreous	8	3.4–3.6	Orth.	C. basal, per. F. uneven
	Flesh-red, redh-brn., olive-grn.	Vitreous	7.5	3.16–3.20	Orth.; us. prism.	C. prism. F. uneven
	Hair-brn., gry., gryh., grn.	Vitreous	6–7	3.23–3.24	Orth.; us. prism.	C. pinac. per. F. uneven

		Name	Composition
	Us. bladed xls.; scratched by knife parallel to cleav. but not at right angles to cleav.	**CYANITE** (Disthene) T434 S500	$(AlO)_2SiO_3$
	Extremely hard. Alexandrite is grn. by daylight (and by incandescent gas light); red by lamplight	**Chrysoberyl** (Alexandrite) T342 S229	$GlAl_2O_4$
	Extremely hard. Emery contains magnetite, hematite, or spinel intimately mixed w. corundum	**CORUNDUM** (Sapphire, blue; Ruby, red; Emery, black) T333 S210	Al_2O_3
Cr in s.ph. bd.	Col. blk.; st. dk. brn.; bd. shows Fe reac. while hot and Cr on cooling	**CHROMITE** (Chromic Iron) T341 S228	$FeCr_2O_4$ (Mg iso. w. Fe; Al
	Dk. yelh-brn. to grnh-brn. Xls. us. octahedrons	**Pictotite** (Chrome Spinel) T338 S221	$(Fe,Mg)(Cr,Al)_2O$
	Insol. skeleton of sil. remains in bd.	**Uvarovite** (Ca-Cr Garnet) T417 S444	$Ca_3Cr_2(SiO_4)_3$ (Al iso. w. Cr)
Little or no Cr, but fine powder wholly sol. in s.ph. bd. (no silica)	Xls. us. octahedrons, often twins; dark varieties react for Fe	**SPINEL** (Spinel Ruby, red) T338 S220	$MgAl_2O_4$ (Fe, Mn iso. w. Mg; Fe, Cr iso. w. Al)
	Wh. ZnO subl. w. soda and borax on ch.; grn. w. $Co(NO_3)_2$	**Gahnite** (Zinc Spinel) T339 S223	$ZnAl_2O_4$ (Mn, Fe iso. w. Zn;
	Mag. mass when fused w. a little soda on ch.	**Hercynite** (Iron Spinel) T339 S223	$FeAl_2O_4$
Distinct cl. at 90° or nearly 90°	Fus. about 5	**FELDSPARS** See Section 23	
Extremely hard; not affected by acids or alkalis; burns in O	Xls. us. octahedrons w. curved faces and brilliant adamantine luster. Bort, rough rounded forms, confused xln.; carbonado, massive, dark gray to black	**DIAMOND** (Carbonado: Carbon; Bort) T271 S3	C (Slight ash in Carb

ı	Color.	Luster.	Hard-ness.	Specific Gravity.	Crystallization.	Cleavage and Fracture.
	Blue, grn., gry., wh.	Vitr. to pearly	5–7.25	3.56–3.67	Tri.; us. bladed	C. pinac. per. P. basal
	Yelh-grn., asparagus-grn. to emerald-grn.	Vitreous	8.5	3.5–3.84	Orth.; us. tab.	C. dome (011) F. uneven, conch.
	Wh., gry., pink., red, yel., grn., blue, brn., blk.	Adamant. to vitr.	9	3.95–4.1	Hex. rhom.	P. basal and rhom. F. uneven
. Cr)	Fe-blk. to brnh-blk.	Dull to submet.	5.5	4.32–4.57	Iso.; us. mass.	F. uneven
	Yelh. or grnh-brn. to brnh-blk.	Pitchy to submet.	7.5–8	4.08–4.11	Iso.; us. mass.	F. uneven
	Emerald-grn.	Vitreous	7.5	3.41–3.52	Iso.	F. conch.
	Red., lavender, blue, grn., brn., blk.	Vitreous	8	3.5–4.1	Iso.; us. oct.	F. conch.
'e w. Al)	Dk., grn., brn. to blk.	Vitreous	7.5–8	4–4.6	Iso.; us. oct.	F. conch., uneven
	Blk.	Vitreous	7.5–8	3.9–3.95	Iso.; us. mass.	F. conch.
:						
ado)	Cols., yel., red, blue, gry., blk.	Adamant. to greasy	10	3.516–3.525	Iso.; us. oct.	C. oct. per. F. conch.

MINERALS ARRANGED ACCORDING TO CRYSTALLIZATION, LUSTER, AND HARDNESS

These tables will often assist in the recognition of minerals without resort to chemical tests. Page references are given to the preceding tables for full descriptions.

ISOMETRIC: Metallic or Submetallic Luster

H.		H.	
1.5	Lead (p. 72)	4	**Stannite** (p. 70)
2–2.5	**Argentite** (p. 70)	4–4.5	**Platinum** (p. 80)
2.5	**GALENA** (p. 70)	4–5	**Iron** (p. 76)
2.5–3	**GOLD** (p. 72)	5.5	**CHROMITE** (pp. 78, 126, 132)
2.5–3	**SILVER** (p. 72)	5.5	**Cobaltite** (p. 66)
2.5–3	**ELECTRUM** (p. 72)	5.5	**Linnaeite** (p. 70)
2.5–3	**COPPER** (p. 72)	5.5	**Perovskite** (pp. 78, 126)
2.5–3	**Hessite** (p. 74)	5.5	**Uraninite** (p. 80)
3	**BORNITE** (p. 70)	5.5	**Gersdorfite** (p. 66)
3	Altaite (p. 76)	5.5–6	**Smaltite** (p. 66)
3–3.5	Amalgam (p. 72)	5.5–6	**Chloanthite** (p. 66)
3–4	**TETRAHEDRITE** (p. 68)	5.5–6.5	**MAGNETITE** (pp. 72, 76)
3–4	**Tennantite** (p. 66)	5.5–6.5	**FRANKLINITE** (p. 76)
3–4	**Freibergite** (p. 68)	6–6.5	**PYRITE** (p. 70)
3.5–4	**SPHALERITE** (pp. 70, 118, 124)	6–7	Martite (pp. 72, 76, 86)
3.5–4	**CUPRITE** (pp. 74, 84)	6–7	Iridium (p. 80)
3.5–4	**Pentlandite** (p. 70)	6–7	Sperrylite (p. 66)
3.5–4	**Alabandite** (p. 72)		

ISOMETRIC: Non-metallic Luster

1–1.5	**Cerargyrite** (p. 86)	5.5–6	**LEUCITE** (p. 122)
1–1.5	**Embolite** (p. 86)	5.5–6	**Sodalite** (p. 100)
1.5	Arsenolite (p. 80)	5.5–6	Hauynite (p. 100)
2	**SYLVITE** (p. 92)	5.5–6	Danalite (pp. 90, 100, 120)
2–2.5	**Kalinite** (pp. 94, 116, 118)	6–6.5	Helvite (pp. 90, 100)
2–2.5	**Senarmontite** (p. 80)	6–7	Martite (pp. 72, 76, 86)
2–3	Bromyrite (p. 86)	6.5–7	**ANDRADITE** (pp. 90, 112)
2.5	**HALITE** (p. 92)	6.5–7	**GROSSULARITE** (p. 112)
2.5	**Pharmacosiderite** (p. 88)	7	**Boracite** (pp. 98, 108)
3.5–4	**SPHALERITE** (pp. 70, 118, 124)	7–7.5	**ALMANDITE** (pp. 90, 112)
3.5–4	**CUPRITE** (pp. 74, 84)	7–7.5	**SPESSARTITE** (pp. 110, 112)
4	**FLUORITE** (p. 96)	7–7.5	**PYROPE** (p. 112)
5–5.5	**ANALCITE** (p. 102)	7–7.5	**Uvarovite** (pp. 112, 132)
5–5.5	**Lazurite** (p. 100)	7.5–8	**Gahnite** (p. 132)
5–5.5	**Pyrochlore** (p. 126)	7.5–8	Hercynite (p. 132)
5.5	**CHROMITE** (pp. 78, 126, 132)	7.5–8	Picotite (p. 132)
5.5	**Perovskite** (pp. 78, 126)	8	**SPINEL** (p. 132)
5.5	Noselite (p. 100)	10	**DIAMOND** (p. 132)
5.5	Microlite (p. 126)		

TETRAGONAL: Metallic or Submetallic Luster

H.	Mineral
3.5–4	CHALCOPYRITE (p. 70)
5–5.5	Hausmannite (p. 78)
5.5–6	Octahedrite (pp. 78, 130)
5.5–6	Fergusonite (pp. 80, 130)
6–6.5	RUTILE (pp. 78, 130)
6–6.5	Braunite (pp. 74, 78)

TETRAGONAL: Non-metallic Luster

H.	Mineral
1–2	Calomel (p. 82)
2–2.5	Torbernite (p. 84)
2.75–3	Wulfenite (p. 82)
2.75–3	Phosgenite (p. 82)
4–5	Xenotime (p. 124)
4.5–5	APOPHYLLITE (p. 102)
4.5–5	Scheelite (pp. 110, 126)
5	Melilite (p. 102)
5–6	WERNERITE (pp. 104, 114)
5.5–6	Octahedrite (pp. 78, 130)
5.5–6	Fergusonite (pp. 80, 130)
5.5–6	Meionite (p. 104)
6–6.5	RUTILE (pp. 78, 130)
6–7	CASSITERITE (p. 130)
6.5	VESUVIANITE (p. 114)
7.5	ZIRCON (p. 130)

HEXAGONAL: Metallic or Submetallic Luster

H.	Mineral
1–1.5	MOLYBDENITE (?) (p. 78)
1–2	GRAPHITE (p. 78)
1.5–2	Tetradymite (p. 76)
1.5–2	Covellite (p. 70)
2–2.5	Bismuth (p. 72)
2–2.5	Tellurium (p. 74)
2.5	Pyrargyrite (pp. 68, 84)
3–3.5	Millerite (p. 70)
3–3.5	Antimony (p. 68)
3.5	Arsenic (p. 66)
3.5–4.5	PYRRHOTITE (p. 70)
5–5.5	Niccolite (p. 66)
5–6	ILMENITE (pp. 76, 78)
5.5–6.5	HEMATITE (pp. 72, 76, 86, 120)
6–7	Iridosmine (p. 80)

HEXAGONAL: Non-metallic Luster

H.	Mineral
1 (?)	Carnotite (?) (p. 98)
1	Bismite (p. 86)
1.5	Iodyrite (p. 86)
1.5–2	SODA NITER (p. 94)
2	Chalcophyllite (p. 84)
2–2.5	CINNABAR (p. 82)
2–2.5	Proustite (p. 84)
2–2.5	Coquimbite (p. 88)
2.5	Brucite (pp. 116, 120)
2.5	Pyrargyrite (pp. 68, 84)
2.5–3.5	Jarosite (p. 88)
2.75–3	Vanadinite (p. 82)
3	CALCITE (p. 116)
3–3.5	Greenockite (p. 118)
3–3.5	Hanksite (p. 92)
3.5	Mimetite (p. 82)
3.5	Thaumasite (p. 116)
3.5–4	PYROMORPHITE (p. 82)
3.5–4	SIDERITE (pp. 86, 118)
3.5–4	DOLOMITE (p. 116)
3.5–4	Ankerite (p. 116)
3.5–4	Alunite (pp. 116, 126)
3.5–4.5	RHODOCHROSITE (p. 118)
3.5–4.5	MAGNESITE (pp. 116, 118)
3.5–4.5	Breunnerite (pp. 116, 118)
4–4.5	ZINCITE (p. 120)
4.5	CHABAZITE (p. 104)
4.5	Gmelinite (p. 104)
4.5–5	APATITE (pp. 96, 120)
5	SMITHSONITE (pp. 118, (98, 120))
5	Dioptase (p. 120)
5–5.5	Eudialite (p. 100)
5–6	Cancrinite (p. 98)
5.5	WILLEMITE (p. 120)
5.5	TROOSTITE (p. 100)
5.5–6	NEPHELITE (p. 102)
5.5–6.5	HEMATITE (pp. 72, 76, 86, 120)
6.25–6.5	Benitoite (p. 110)
7	QUARTZ (p. 130)
7	Tridymite (p. 130)
7–7.5	TOURMALINE (pp. 108, 128)
7.5–8	BERYL (pp. 114, 128)
7.5–8	Phenacite (p. 130)
9	CORUNDUM (p. 132)

ORTHORHOMBIC: Metallic or Submetallic Luster

H.		H.	
1–1.5	Nagyagite (p. 76)	4	MANGANITE (p. 78)
1–1.5	Sternbergite (p. 70)	5	Glaucodot (p. 66)
2	STIBNITE (p. 68)	5–5.5	GOETHITE (pp. 74, 76, 86, 120)
2	Bismuthinite (p. 72)	5–5.5	Löllingite (p. 66)
2–2.5	Stephanite (p. 68)	5–5.5	Yttr tantalite (pp. 80, 126, 128)
2–3	Jamesonite (p. 68)	5–6	Samarskite (pp. 74, 110)
2.5	Krennerite (p. 74)	5.5–6	ARSENOPYRITE (p. 66)
2.5–3	CHALCOCITE (p. 70)	5.5–6	Brookite (pp. 78, 130)
2.5–3	Stromeyerite (p. 70)	5.5–6	Ilvaite (pp. 74, 90)
2.5–3	Bournonite (p. 68)	6	COLUMBITE (pp. 74, 80, 110, 130)
2.5–3	Boulangerite (p. 68)	6	Pseudobrookite (p. 76)
3	Enargite (p. 66)	6	Tantalite (pp. 80, 130)
3–3.5	Zinkenite (p. 68)	6–6.5	MARCASITE (p. 70)
3.5–4	Dyscrasite (p. 68)		

ORTHORHOMBIC: Non-metallic Luster

1	Carnallite (p. 92)	4.5–5	CALAMINE (pp. 98, 120, (118))
1–2	Molybdite (p. 98)	4.5–5	Triphylite (p. 88)
1–2.5	TALC (?) (pp. 106, 114, 124)	4.5–5	Lithiophylite (p. 96)
1.5–2.5	SULPHUR (p. 80)	4.5–5	Childrenite (p. 88)
2	NITER (p. 94)	5–5.5	NATROLITE (p. 98)
2–2.5	Epsomite (p. 94)	5–5.5	GOETHITE (pp. 74, 76, 86, 120)
2–2.5	Autunite (p. 96)	5–5.5	Thomsonite (p. 100)
2–2.5	Goslarite (p. 118)	5–5.5	Yttrotantalite (pp. 80, 126, 128)
2–3	Thenardite (p. 94)	5–6	Hypersthene (pp. 90, 126)
2.5–3	Valentinite (p. 80)	5–6	Samarskite (pp. 74, 110)
2.5–3	Caledonite (p. 82)	5–6	Polycrase (p. 130)
2.5–3.5	BARITE (p. 96)	5.5	ENSTATITE (pp. 112, 128)
2.75–3	ANGLESITE (p. 82)	5.5–6	Anthophyllite (pp. 90, 112, 128)
3	Astrophyllite (p. 88)	5.5–6	Brookite (pp. 78, 130)
3	Olivenite (p. 84)	5.5–6	Tephroite (p. 100)
3	Sussexite (?) (p. 98)	5.5–6	Ilvaite (pp. 74, 90)
3–3.5	CERUSITE (p. 82)	6	COLUMBITE (pp. 74, 80, 110, 130)
3–3.5	CELESTITE (p. 96)	6	Tantalite (pp. 80, 130)
3–3.5	ANHYDRITE (p. 94)	6–6.5	PREHNITE (pp. 102, 114)
3–3.5	Atacamite (p. 84)	6–6.5	ZOISITE (p. 114)
3–3.75	WITHERITE (p. 94)	6–6.5	Humite (p. 122)
3–4	Wavellite (p. 124)	6–7	SILLIMANITE (p. 130)
3.5	Adamite (p. 98)	6.5	Fayalite (p. 90)
3.5	Descloizite (p. 82)	6.5–7	CHRYSOLITE (p. 122)
3.5–4	ARAGONITE (p. 116)	6.5–7	Diaspore (p. 128)
3.5–4	STRONTIANITE (p. 116)	7–7.25	Danburite (p. 108)
3.5–4	Brochantite (p. 84)	7–7.5	Iolite (pp. 114, 128)
3.5–4	Scorodite (p. 88)	7–7.5	Staurolite (p. 128)
3.5–4	Euchroite (p. 84)	7.5	ANDALUSITE (p. 130)
3.5–4	Dufrenite (p. 88)	8	TOPAZ (p. 130)
4	Libethenite (p. 84)	8.25	Lawsonite (p. 114)
4	Variscite (p. 124)	8.5	Chrysoberyl (p. 130)
4–4.5	Purpurite (?) (p. 96)		

MONOCLINIC: Metallic or Submetallic Luster

H.	
1.5–2	Sylvanite (p. 74)
2–2.5	Freieslebenite (p. 68)
2–3	Polybasite (p. 68)
3	Pearceite (p. 66)

H.	
3–4	Tenorite (p. 74)
4–4.5	Ferberite (pp. 74, 90)
5–5.5	WOLFRAMITE (pp. 74, 90, 110)
5.5–6	Allanite (pp. 74, 90, 102)

MONOCLINIC: Non-metallic Luster

1–1.5	Vermiculite (?) (p. 102)
1–1.5	Natron (p. 92)
1–1.5	Kermesite (p. 80)
1–2	Aluminite (p. 118)
1–2.5	CHLORITE (pp. 106, 124)
1–2.5	KAOLINITE (p. 126)
1.5–2	GYPSUM (p. 94)
1.5–2	ORPIMENT (p. 80)
1.5–2	REALGAR (p. 80)
1.5–2	Vivianite (p. 88)
1.5–2	Mirabilite (p. 94)
1.5–2	Alunogen (p. 118)
1.5–2.5	Erythrite (p. 88)
1.5–2.5	Annabergite (p. 88)
2	Melanterite (p. 88)
2	Aurichalcite (p. 118)
2	Thomsenolite (p. 96)
2–2.5	MUSCOVITE (p. 106)
2–2.5	BORAX (pp. 94, 96)
2–2.5	Kämmererite (pp. 106, 124)
2–2.5	Pharmacolite (p. 98)
2–2.5	Liroconite (p. 84)
2–3	Gay-Lussite (p. 94)
2.5	CRYOLITE (p. 96)
2.5	Cookeite (p. 106)
2.5	Linarite (p. 82)
2.5	Leadhillite (p. 82)
2.5	Copiapite (p. 88)
2.5–3	PHLOGOPITE (p. 106)
2.5–3	BIOTITE (pp. 88, 90, 106)
2.5–3	Trona (p. 92)
2.5–3	Clinoclasite (p. 84)
2.5–3	Crocoite (p. 82)
2.5–3	Polyhalite (p. 94)
2.5–3	Glauberite (p. 94)
2.5–3	Kainite (p. 92)
2.5–3	Paragonite (p. 106)
2.5–3	Zinnwaldite (pp. 90, 106)
2.5–3.5	Gibbsite (p. 126)
2.5–4	LEPIDOLITE (p. 106) [106)
3	LEPIDOMELANE (pp. 88,
3	Pachnolite (p. 96) [118)
3.5	Hydromagnesite (pp. 116,
3.5–4	MALACHITE (p. 84)
3.5–4	AZURITE (p. 84)
3.5–4	STILBITE (p. 104)
3.5–4	HEULANDITE (p. 104)

3.5–4	Laumontite (p. 100)
3.5–4.5	Margarite (pp. 106, 124)
4	Barytocalcite (p. 116)
4–4.5	Ferberite (pp. 74, 90)
4–4.5	Colemanite (p. 98)
4–4.5	Phillipsite (p. 104)
4–5	Seybertite (p. 124)
4.5	Harmotome (pp. 104, 114)
4.5–5	WOLLASTONITE (p. 104)
4.5–5	Triplite (p. 88)
5	Pectolite (pp. 100, 102)
5	Mesolite (p. 100)
5	Herderite (pp. 96, 114)
5–5.5	MONAZITE (p. 124)
5–5.5	DATOLITE (p. 98)
5–5.5	TITANITE (pp 104, 110)
5–5.5	WOLFRAMITE (pp. 74, 90, 110)
5–5.5	Hübnerite (p. 110)
5–5.5	Scolecite (p. 100)
5–5.5	Wagnerite (p. 96)
5–6	PYROXENE (pp. 112, 114)
5–6	AUGITE (p. 114)
5–6	DIOPSIDE (p. 112)
5–6	AMPHIBOLE (p. 112)
5–6	HORNBLENDE (p. 112)
5–6	TREMOLITE (p. 112)
5–6	ACTINOLITE (p. 112)
5–6	Jeffersonite (p. 110)
5–6	Lazulite (p. 124)
5–6	Hedenbergite (p. 112)
5–6	Schefferite (p. 110)
5.5–6	Richterite (p. 110)
5.5–6	Allanite (pp. 74, 90, 102)
6	ORTHOCLASE (p. 108)
6	Arfvedsonite (p. 92)
6	Riebeckite (p. 92)
6–6.5	Acmite (pp. 92, 114)
6–6.5	Petalite (p. 108)
6–6.5	Chondrodite (p. 122)
6–6.5	Clinohumite (p. 122)
6–6.5	Glaucophane (p. 112)
6–7	EPIDOTE (pp. 90, 114)
6.5	Piedmontite (p. 110)
6.5–7	SPODUMENE (p. 108)
6.5–7	Jadeite (p. 114)
6.5–7	Gadolinite (pp. 102, 122)

TRICLINIC: Non-metallic Luster

H.	
1	**Sassolite** (p. 98)
2.5	**Chalcanthite** (p. 84)
5–6	**ANDESINE** (p. 108)
5–6	**LABRADORITE** (pp. 104, 108)
5–7.25	**CYANITE** (pp. 126, 132)
5.5–6.5	**RHODONITE** (p. 110)
5.5–6.5	Fowlerite (p. 110)
6	**Turquois** (p. 128)
6	**Amblygonite** (p. 108)
6–6.5	**MICROCLINE** (p. 108)
6–6.5	**ALBITE** (p. 108)
6–6.5	**OLIGOCLASE** (p. 108)
6–6.5	**ANORTHITE** (pp. 102, 108)
6–7	**Ottrelite** (?) (p. 128)
6.5	Chloritoid (?) (p. 128)
6.5–7	**Axinite** (p. 108)
7.25	**CYANITE** (pp. 126, 132)

AMORPHOUS OR CRYSTALLIZATION UNKNOWN

Metallic or Submetallic Luster

0	Mercury (p. 72)
1–6	**WAD** (pp. 78, 120)
2–2.5	**PYROLUSITE** (p. 78)
2.5	**Calaverite** (p. 76)
2.5–3	**Petzite** (p. 74)
3–3.5	Domeykite (p. 66)
3.5	Whitneyite (p. 66)
4	Algodonite (p. 66)
5–5.5	**LIMONITE** (pp. 74, 76, 86, 120)
5–6	**PSILOMELANE** (p. 78)
5–6	**TURGITE** (pp. 74, 76, 86, 120)

AMORPHOUS OR CRYSTALLIZATION UNKNOWN

Non-metallic Luster

1	**Ulexite** (p. 96)
1	Saponite (p. 124)
1 (?)	Nitrocalcite (p. 94)
1–2	**PYROPHYLLITE** (p. 124)
1–2	Halloysite (p. 122)
1–2	Hydrocuprite (p. 8)
1–2.5	Asbolite (p. 120)
1–3	**BAUXITE** (p. 126)
1–4	**Garnierite** (pp. 122, 126)
1–6	**WAD** (pp. 78, 120)
2	Massicot (p. 82)
2–2.5	Sepiolite (pp. 102, 122)
2–2.5	Hydrozincite (p. 118)
2–3.5	**Deweylite** (pp. 102, 122)
2–4	**Chrysocolla** (p. 122)
2.5–4.5	Chloropal (p. 122)
2.5–5	**SERPENTINE** (pp. 102, 122)
3	**Allophane** (p. 122)
3–3.25	**Zaratite** (p. 118)
3.5	Howlite (p. 108)
4	Crocidolite (p. 92)
4–4.5	Bismutite (p. 86)
4–5.5	**SERPENTINE** (pp. 102, 122)
5–5.5	**LIMONITE** (pp. 74, 76, 86, 120)
5–6	**TURGITE** (pp. 74, 76, 86, 120)
5.5–6.5	**OPAL** (p. 128)

GENERAL INDEX

Abbreviations, 58, 60
Acids, 4, 5
  use of, 23
Agate mortar, 3
Aluminum, tests for, 26
Ammonia, 5
Ammonium carbonate, 5
  hydroxide, 5
  molybdate, 5
  oxalate, 5
Amorphous minerals, 139
Antimony, tests for, 26
Anvil, 2
Apparatus, 1
Aqua fortis, 5
Aqua regia, 5
Arsenic, tests for, 27
Atomic weights, 58

Barium, tests for, 28
  chloride, 5
Bases in silicates, 41
Bismuth, tests for, 28
Bismuth flux, 4
Blast, 6
Blowpipe, 1
Blowpipe operations, 6
Blue glass, 2
Borax, 4
Borax bead, 19, 20
Boric acid flux, 4
Boron, tests for, 29
Bromine, tests for, 29

Cadmium, tests for, 29
Calcium, tests for, 29
Carbon, tests for, 30
Caustic potash, 5
Charcoal, 1
  sublimates on, 13
  use of, 12
Charcoal brush, 3
Chemical elements, 58
Chemical tests, 6, 26
Chlorine, tests for, 31
Chromium, tests for, 31
Closed tubes, 2
  sublimates in, 16
  use of, 14
Cobalt, tests for, 32
  nitrate, 5
  use of, 24
Columbium, tests for, 32
Copper, tests for, 32
Crystallization, 47
  table of, 135

Decrepitation, 8
Descriptive terms, 53
Determinative tables, 64
Diamond mortar, 3

Elements, table of, 58
  tests for, 26

Filter-paper, 3
Flames, 6

Flame colors, 10
Fluorine, tests for, 33
Forceps, 1
Funnel, 3
Fusibility, 9
Fusion, 7

Galena, as reagent, 4
General table, 64
Glass funnel, 3
Glossary, 53
Gold, tests for, 33
Green glass, 2
Gypsum, as reagent, 4
Gypsum tablets, 3
  sublimates on, 15
  use of, 14

Hammer, 2
Hardness, scale of, 54
  table of, 135
Hexagonal system, 49, 50, 136
Hydrochloric acid, 4
Hydrogen, tests for, 33

Ignition, 7
Iodide sublimates, 15
Iodine, tests for, 34
Iridium, tests for, 34, 39
Iridosmine, tests for, 39
Iron, tests for, 34
Isometric system, 47, 48, 135

Lamp, 1
Lead, tests for, 35
Lithium, tests for, 35
Litmus paper, 4

Magnesium, tests for, 36
Magnet, 2
Manganese, tests for, 36
Mercury, tests for, 37
Microcosmic salt, 4
  bead of, 21, 22
Mineral tables, 64, 135
  precautions concerning, 63
Molybdenum, tests for, 37
Monoclinic system, 51, 52, 138
Mortars, 3
Muriatic acid, 4

Nickel, tests for, 37
Niobium, see Columbium.
Nitric acid, 5
Nitrogen, tests for, 38

Oil of vitriol, 5
Open tubes, 2
  sublimates in, 18
  use of, 17
Orthorhombic system, 51, 137
Osmium, tests for, 38, 39
Oxygen, tests for, 38

Palladium, tests for, 38, 39
Phosphorus, tests for, 38
Phosphorus salt, 4
  bead of, 21, 22
Platinum, tests for, 39
  wire, 2
Porcelain crucible, 3
Potash, caustic, 5
Potassium, tests for, 39
  bisulphate, 4
  ferricyanide, 5
  ferrocyanide, 5
  hydroxide, 5
Precautions concerning tables, 63
Precipitates, 25

Quicksilver, tests for, 37

Reactions for elements, 26
Reagents, 4
Roasting, 14

Salt of phosphorus, 4
  bead of, 21, 22
Scale of fusibility, 9
Selenium, tests for, 40
Silicon, tests for, 40
Silver, tests for, 41

Silver nitrate, 5
Soda, 4
  bead of, 23
Sodium, tests for, 42
Sodium ammonium phosphate, 4
  bead of, 21, 22
Sodium carbonate, 4
  bead of, 23
Sodium phosphate, 5
Sodium tetraborate, 4
  bead of, 19, 20
Solution in acids, 23
Streak plate, 2
Strontium, tests for, 42
Sublimates in closed tube, 16
  in open tube, 18
  on charcoal, 13, 15
  on gypsum, 15
Sulphates, tests for, 43
Sulphides, tests for, 43
Sulphur, tests for, 43
Sulphuric acid, 5
Symbols of elements, 58

Table of borax bead reactions, 20
  flame colors, 10
  salt of phosphorus bead reactions, 22
  sublimates in closed tube, 16
  sublimates in open tube, 18
    on charcoal, 13, 15
    on gypsum, 15
Technical terms, 53
Tellurium, tests for, 44
Test papers, 4
Test tubes, 2
Test-tube holder, 2
  support, 3
Tests for bases in silicates, 41
Tests for elements, 26
Tetragonal system, 49, 136
Tin, tests for, 44
  as reagent, 4
Titanium, tests for, 44
Triclinic system, 52, 139
Tungsten, tests for, 45
Turmeric paper, 4

Uranium, tests for, 45

Vanadium, tests for, 45

Watch glasses, 3
Water, 4

Zinc, tests for, 45
  as reagent, 4
Zirconium, tests for, 46

INDEX TO MINERALS

Achroite, 108, 128
Acmite, 92, 114
Actinolite, 112
Adamite, 98
Aegirite, 92, 114
Agalmatolite, 124
Agate, 130
Alabandite, 72
Alabaster, 94
Albite, 108
Alexandrite, 132
Algodonite, 66
Allanite, 74, 90, 102
Allophane, 122
Almandite, 90, 112
Altaite, 76
Aluminite, 118
Aluminum ore, 126
Alunite, 116, 126
Alunogen, 118
Amalgam, 72
Amblygonite, 108
Amethyst, 130
Amphibole Group, 112
Analcite, 102
Anatase, 130
Andalusite, 130
Andesine, 108
Andradite, 90, 112
Anglesite, 82
Anhydrite, 94
Ankerite, 116
Annabergite, 88
Anorthite, 102, 108
Anthophyllite, 90, 112, 128
Antimony, 68
Antimony Glance, 68
Apatite, 96, 120
Apophyllite, 102
Aquamarine, 114, 128
Aragonite, 116
Arfvedsonite, 92
Argentite, 70
Arsenic, 66
Arsenolite, 80
Arsenopyrite, 66
Asbestos, 90, 112, 128
Asbolite, 120
Astrophyllite, 88
Atacamite, 84
Augite, 114
Aurichalcite, 118
Autunite, 96
Axinite, 108
Azurite, 84

Barite, 96
Barytocalcite, 116
Bauxite, 126
Benitoite, 110
Beryl, 114, 128
Biotite, 88, 90, 106
Bismite, 86
Bismuth, 72
Bismuth Glance, 72
Bismuthinite, 72

Bismutite, 86
Black Jack, 70
Black Lead, 78
Black Mica, 88, 90, 106
Blende, 70, 118, 124
Bog Iron Ore, 74, 76, 86, 120
Bog Manganese, 78, 120
Boracite, 98, 108
Borax, 94, 96
Boric Acid, 98
Bort, 132
Bornite, 70
Boronatrocalcite, 96
Boulangerite, 68
Bournonite, 68
Braunite, 74, 78
Breunnerite, 116, 118
Brittle Mica, 106, 124
Brittle Silver, 68
Brochantite, 84
Bromyrite, 86
Bronzite, 112
Brookite, 78, 130
Brown Hematite, 74, 76, 86, 120
Brown Spar, 116, 118
Brucite, 116, 120

Ca-Al, Garnet, 112
Ca-Cr Garnet, 112, 132
Ca-Fe Garnet, 90, 112
Calamine, 98, (118), 120
Calaverite, 76
Calcite, 116
Calc Spar, 116
Caledonite, 82
Calomel, 82
Cancrinite, 98
Carbon, 132
Carbonado, 132
Carnallite, 92
Carnotite, 98
Cassiterite, 130
Celestite, 96
Cerargyrite, 86
Cerusite, 82
Chabazite, 104
Chalcanthite, 84
Chalcedony, 130
Chalcocite, 70
Chalcophyllite, 84
Chalcopyrite, 70
Chalk, 116
Chert, 130
Chiastolite, 130
Childrenite, 88
Chloanthite, 66
Chlorite, 106, 124
Chloritoid, 128
Chloropal, 122
Chondrodite, 122
Chrome Chlorite, 106, 124
Chrome Garnet, 112, 132
Chrome Spinel, 132
Chromic Iron, 78, 126, 132
Chromite, 78, 126, 132
Chrysoberyl, 132
Chrysocolla, 122
Chrysolite, 122
Chrysotile, 102, 122
Cinnabar, 82
Clinochlore, 106, 124
Clinoclasite, 84
Clinohumite, 122
Clintonite, 124
Cobalt Bloom, 88
Cobaltite, 66
Colemanite, 98
Columbite, 74, 80, 110, 130
Cookeite, 106
Copiapite, 88
Copper, 72
Copper Glance, 70
Copper Nickel, 66
Copper Pyrites, 70
Copperas, 88
Coquimbite, 88
Cordierite, 114, 128
Corundum, 132
Covellite, 70
Crocidolite, 92
Crocoite, 82
Cryolite, 96

Cuprite, 74, 84
Cuprodescloizite, 82
Cyanite, 126, 132

Damourite, 106
Danalite, 90, 100, 120
Danburite, 108
Dark Red Silver, 68, 84
Datolite, 98
Descloizite, 82
Desmine, 104
Deweylite, 102, 122
Diallage, 112
Dialogite, 118
Diamond, 132
Diaspore, 128
Diopside, 112
Dioptase, 120
Disthene, 126, 132
Dolomite, 116
Domeykite, 66
Dry Bone, 118
Dufrenite, 88
Dyscrasite, 68

Earthy Cobalt, 120
Elaeolite, 102
Electrum, 72
Embolite, 86
Emerald, 114, 128
Emery, 132
Enargite, 66
Enstatite, 112, 128
Epidote, 90, 114
Epsomite, 94
Epsom Salt, 94
Erythrite, 88
Euchroite, 84
Eucolite, 100
Eudialite, 100

Fayalite, 90
Feather Ore, 68
Feldspar Group, 108
Ferberite, 74, 90
Fergusonite, 80, 130
Fibrolite, 130
Flint, 130
Fluorite, 96
Fluor Spar, 96
Fool's Gold, 70
Fowlerite, 110
Franklinite, 76
Freibergite, 68
Freieslebenite, 68

Gadolinite, 102, 122
Gahnite, 132
Galena, 70
Galenite, 70
Garnet Group, 112
Garnierite, 122, 126
Gay-Lussite, 94
Genthite, 122, 126
Gersdorfite, 66
Gibbsite, 126
Glauberite, 94
Glauber Salt, 94
Glaucodot, 66
Glaucophane, 112
Gmelinite, 104
Goethite, 74, 76, 86, 120
Gold, 72
Goslarite, 118
Göthite, 74, 76, 86, 120
Graphite, 78
Gray Copper, 68
Greenockite, 118
Grossularite, 112
Gymnite, 102, 122
Gypsum, 94

Hair Pyrites, 70
Halite, 92
Halloysite, 122
Hanksite, 92
Harmotome, 104, 114
Hausmannite, 78
Hauyne, 100
Hauynite, 100
Heavy Spar, 96
Hedenbergite, 112

Helvite, 90, 100
Hematite, 72, 76, 86, 120
Hemimorphite, 98, 120
Hercynite, 132
Herderite, 96, 114
Hessite, 74
Heulandite, 104
Hiddenite, 108
Hornblende, 112
Horn Silver, 86
Howlite, 108
Hübnerite, 110
Humite, 122
Hyacinth, 130
Hyalite, 128
Hydrargillite, 126
Hydrocuprite, 8
Hydrohematite, 74, 76, 86, 120
Hydromica, 106
Hydromagnesite, 116, 118
Hydrozincite, 118
Hypersthene, 90, 126

Idocrase, 114
Ilmenite, 76, 78
Ilvaite, 74, 90
Indicolite, 108, 128
Iodyrite, 86
Iolite, 114, 128
Iridium, 80
Iridosmine, 80
Iron, 76
Iron-Al Garnet, 90, 112
Iron Dolomite, 116
Iron Magnesite, 116, 118
Iron Pyrites, 70
Iron Spinel, 132

Jade, 112, 114
Jadeite, 114
Jamesonite, 68
Jarosite, 88
Jasper, 130
Jefferisite, 102
Jeffersonite, 110

Kainite, 92
Kalinite, 94, 116, 118
Kämmererite, 106, 124
Kaolin, 126
Kaolinite, 126
Kermesite, 80
Krennerite, 74
Kunzite, 108

Labradorite, 104, 108
Lapis Lazuli, 100
Laumontite, 100
Lawsonite, 114
Lazulite, 124
Lazurite, 100
Lead, 72
Leadhillite, 82
Lepidolite, 106
Lepidomelane, 88, 106
Leucite, 122
Leucopyrite, 66
Libethenite, 84
Lievrite, 74, 90
Lime-Al Garnet, 112
Lime Feldspar, 102, 108
Lime-iron Garnet, 90, 112
Lime-soda, Feldspar, 104, 108
Limestone, 116
Limonite, 74, 76, 86, 120
Linarite, 82
Linnaeite, 70
Liroconite, 84
Lithia Mica, 106
Lithiophylite, 96
Lodestone, 72, 76
Löllingite, 66

Magnesia-Al Garnet, 112
Magnesia Mica, 106
Magnesite, 116, 118
Magnetic Iron Ore, 72, 76
Magnetic Pyrites, 70
Magnetite, 72, 76
Malachite, 84
Manganese Amphibole, 110
Manganese Epidote, 110

Manganese Garnet, 110, 112
Manganese Pyroxene, 110
Manganese-Zn Pyroxene, 110
Manganite, 78
Marble, 116
Marcasite, 70
Margarite, 106, 124
Marmolite, 102, 122
Martite, 72, 76, 86
Massicot, 82
Meerschaum, 102, 122
Meionite, 104
Melaconite, 74
Melanterite, 88
Melilite, 102
Menaccanite, 76, 78
Mercury, 72
Mesolite, 100
Meteoric Iron, 76
Mica Group, 106
Microcline, 108
Microlite, 126
Millerite, 70
Mimetite, 82
Mirabilite, 94
Mispickel, 66
Molybdenite, 78
Molybdite, 98
Monazite, 124
Mundic, 70
Muscovite, 106

Nagyagite, 76
Natrocalcite, 94
Natrolite, 98
Natron, 92
Nepheline, 102
Nephelite, 102
Nephrite, 112
Niccolite, 66
Nickel Bloom, 88
Niter, 94
Nosean, 100
Noselite, 100

Octahedrite, 78, 130
Oligoclase, 108
Olivenite, 84
Olivine, 122
Opal, 128
Orpiment, 80
Orthite, 74, 90
Orthoclase, 108
Osmiridium, 80
Ottrelite, 128

Pachnolite, 96
Paragonite, 106
Paramelaconite, 74
Peacock Ore, 70
Pearceite, 66
Pearl Spar, 116
Pectolite, 100, 102
Penninite, 106, 124
Pentlandite, 70
Peridot, 122
Perofskite, 78, 126
Perovskite, 78, 126
Petalite, 108
Petzite, 74
Pharmacolite, 98
Pharmacosiderite, 88
Phenacite, 130
Phillipsite, 104
Phlogopite, 106
Phosgenite, 82
Picotite, 132
Piedmontite, 110
Pistacite, 90, 114
Pitchblende, 80
Plagioclase Feldspars, 108
Platinum, 80
Plumbago, 78
Polybasite, 68
Polycrase, 130
Polyhalite, 94
Porcelain Clay, 126
Potash Alum, 94, 116, 118
Potash Feldspar, 108
Potash Mica, 106
Prehnite, 102, 114
Prochlorite, 106, 124

Proustite, 84
Pseudobrookite, 76
Psilomelane, 78
Purpurite, 96
Pyrargyrite, 68, 84
Pyrite, 70
Pyrochlore, 126
Pyrolusite, 78
Pyromorphite, 82
Pyrope, 112
Pyrophyllite, 124
Pyroxene, 112, 114
Pyroxene Group, 112
Pyrrhotite, 70

Quartz, 130
Quicksilver, 72

Realgar, 80
Red Zinc Ore, 120
Rhodochrosite, 118
Rhodonite, 110
Richterite, 110
Riebeckite, 92
Rock Salt, 92
Rubellite, 108, 128
Ruby, 132
Ruby Silver, 68, 84
Ruby Spinel, 132
Rutile, 78, 130

Sal Soda, 92
Salt, 92
Saltpeter, 94
Samarskite, 74, 110
Saponite, 124
Sapphire, 132
Sassolite, 98
Scapolite, 104, 114
Scheelite, 110, 126
Schefferite, 110
Schorl, 108, 128
Scolecite, 100
Scorodite, 88
Selenite, 94
Senarmontite, 80
Sepiolite, 102, 122
Sericite, 106
Serpentine, 102, 122
Seybertite, 124
Siderite, 86, 118
Sillimanite, 130
Silver, 72
Silver Glance, 70
Silver Tetrahedrite, 68
Smaltite, 66
Smithsonite, (98), 118, (120)
Soapstone, 106, 114, 124
Sodalite, 100
Soda Feldspar, 108
Soda-lime Feldspar, 108
Soda Mica, 106
Soda Niter, 94
Spathic Iron, 86, 118
Specular Iron, 72, 76
Sperrylite, 66
Spessartite, 110, 112
Sphalerite, 70, 118, 124
Sphene, 104, 110
Spinel, 132
Spinel Ruby, 132
Spodumene, 108
Stannite, 70
Staurolite, 128
Steatite, 106, 114, 124
Stephanite, 68
Sternbergite, 70
Stibnite, 68
Stilbite, 104
Stromeyerite, 70
Strontianite, 116
Sulphur, 80
Sussexite, 98
Sylvanite, 74
Sylvite, 92

Talc, 106, 114, 124
Tantalite, 80, 130
Tellurium, 74
Tennantite, 66
Tenorite, 74
Tephroite, 100

Tetradymite, 76
Tetrahedrite, 68
Thaumasite, 116
Thenardite, 94
Thomsenolite, 96
Thomsonite, 100
Tin Pyrites, 70
Tin Stone, 130
Titanic Iron, 76, 78
Titanite, 104, 110
Topaz, 130
Torbernite, 84
Tourmaline, 108, 128
Tremolite, 112
Tridymite, 130
Triphylite, 88
Triplite, 88
Trona, 92
Troostite, 100
Turgite, 74, 76, 86, 120
Turquois, 128

Ulexite, 96
Uraninite, 80
Uvarovite, 112, 132

Valentinite, 80
Vanadinite, 82
Variscite, 124
Vermiculite, 102
Vesuvianite, 114
Vivianite, 88

Wad, 78, 120
Wagnerite, 96
Wavellite, 124
Wernerite, 104, 114
White Iron Pyrites, 70
Whitneyite, 66
Willemite, 120
Witherite, 94
Wolframite, 74, 90, 110
Wollastonite, 104
Wulfenite, 82

Xenotime, 124

Yttrotantalite, 80, 126, 128

Zaratite, 118
Zinc Blende, 70, 118, 124
Zinc Spinel, 132
Zincite, 120
Zinc-Mn Pyroxene, 110
Zinc Rhodonite, 110
Zinkenite, 68
Zinnwaldite, 90, 106
Zircon, 130
Zoisite, 114

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